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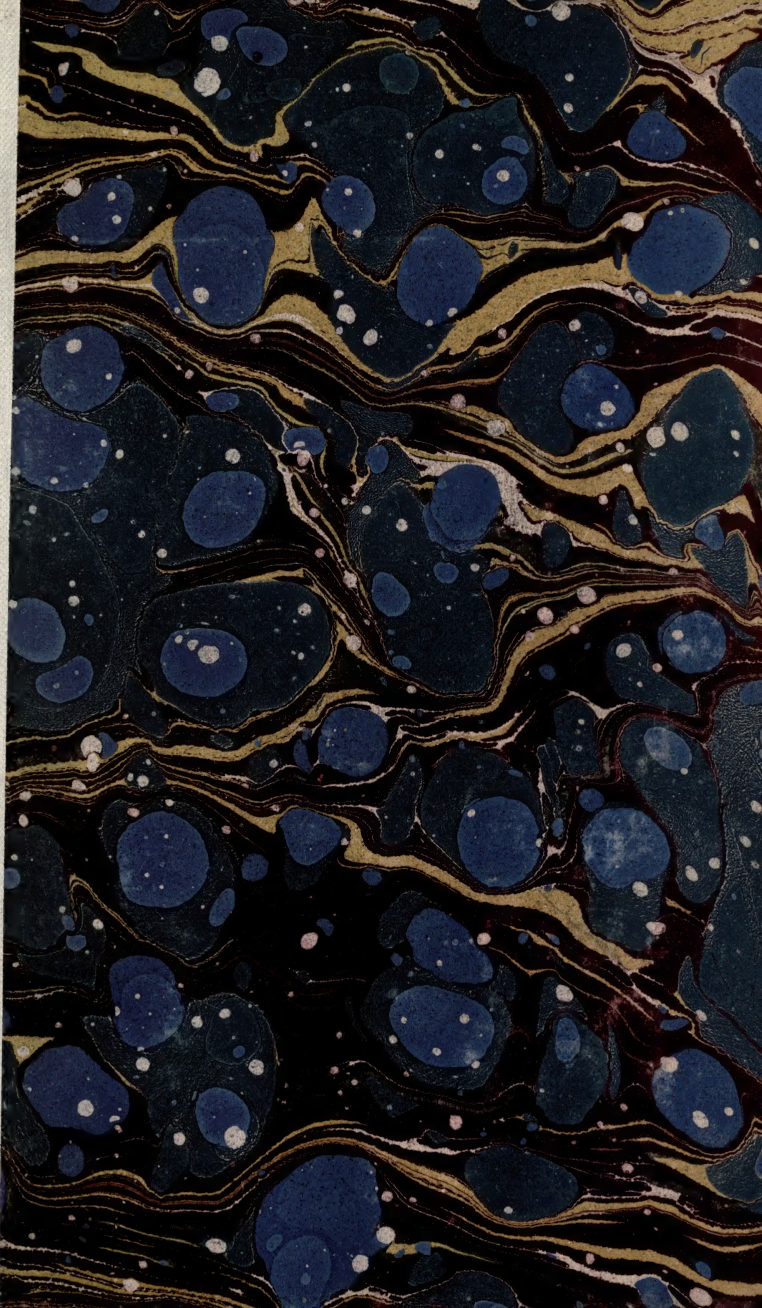

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MANUAL OF ZOOLOGY

A

MANUAL OF ZOOLOGY

FOR THE USE OF STUDENTS

WITH A GENERAL INTRODUCTION ON THE
PRINCIPLES OF ZOOLOGY

BY

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SIXTH EDITION

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PREFACE TO THE SIXTH EDITION.

THE present edition has been submitted to thorough revision, and it is hoped that the most important facts which have been brought to light since the appearance of the last edition will be found to be incorporated in it. No very important changes in classification have been introduced, save that the *Echinodermata*, in accordance with the views of many distinguished naturalists, have been raised to the rank of a sub-kingdom. This alteration necessitates the abandonment of the *Annuloida*, as a sub-kingdom, and the reference of the *Scolecida* to the *Annulosa;* and though this arrangement is far from being wholly satisfactory, it would seem to be the best that can, under the circumstances and with our present knowledge, be adopted.

Lastly, a considerable number of additional illustrations have been introduced, by which, it is hoped, the work of the student will be proportionately lightened; and it is to these, chiefly, that any increase of bulk in the present edition is to be ascribed.

UNITED COLLEGE, ST ANDREWS,
May 24, 1880.

PREFACE TO THE FIFTH EDITION.

THE present edition of this work, in its general ground-plan, is essentially identical with those which have preceded it; but it has, nevertheless, been subjected to very considerable modifications in detail. The original aim of the work was to give, in as clear and concise a form as possible, the chief parts of Systematic Zoology, and to give only such a selection from these as could be readily made available by ordinary students. In the present edition this aim has been faithfully adhered to, and, it is hoped, has been more thoroughly carried out than on previous occasions.

While in the main preserving its original basis, the entire work has been submitted to careful revision, and large portions of it have been almost entirely rewritten. A very considerable amount of new matter has been added; but an undue increase in the size of the book has been prevented by the expedient of printing portions of the text in small type. Some space has also been gained by the omission of the synoptical tables of the families of the various orders and classes of the animal kingdom, which were inserted in former editions; and the space thus gained has been largely taken by bibliographical lists, indicating for each great division of animals the more important sources to which the student may look for original information.

Much of the increase in the bulk of this edition is further due to the fact that nearly one hundred additional illustrations have been introduced, which, it is believed, will materially assist in the comprehension of the text. In connection with this subject, the author has to record here his thanks to Messrs A. & C. Black for their kindness in permitting him to use several of the engravings (viz., figs. 61, 64, 65, 66, 69, 71, 73, 75, 76, 209, 211, and 212) from his articles on Corals and Cuttle-fishes in the ninth edition of the 'Encyclopædia Britannica.'

The only other point which appears to require notice relates to the classification here adopted. This classification, as in the previous editions of the work, is based essentially upon the views put forth by Professor Huxley in his masterly treatise, entitled 'Lectures on the Elements of Comparative Anatomy,' published in 1864. The reader will find a good many minor changes in this classification, necessitated by the recent progress of Zoological science. Thus, the new groups of the Hydrocorallinæ and Helioporidæ of Mosely have been duly recognised; the discovery of the tracheal system of Peripatus has enriched the Myriapoda with a new order; the Theriodontia of Owen have been added to the already numerous groups of the extinct Reptiles; the orders Odontolcæ and Odontotormæ of Marsh, collectively forming the new sub-class Odontornithes, are accessions to the class of Birds; and through the researches of the last-named distinguished palæontologist, the domain of Mammalian life has been extended by the establishment of the Tillodontia and Dinocerata.

In the main, however, the author has not thought it necessary to depart from the broad outlines of the systematic arrangement of animals originally adopted by Professor Huxley, to which he finds himself still able to give his hearty adhesion. The student of some of the more recent German, American, and English zoological publications would, however, find himself confronted with a classification of more modern origin, and in many fundamental points essentially different from the one followed here. Thus, to speak only of conspicuous instances, he would find the Sponges placed with the Cœlenterata; the Rugose Corals would be side by side with the Jelly-fishes in the class of the Hydrozoa; the Polyzoa and Brachiopoda would be met with in the "Vermes," in the immediate neighbourhood of the Annelides; and in looking for the Tunicates he would either have to direct his search to the group just mentioned, or he might even light upon the object of his quest at the bottom of the Vertebrate subkingdom.

That these and other similar changes have not been adopted here demands a few words of explanation. In the first place, the present work is intended principally for the guidance of general students, and the author is of opinion that it would for this reason be improper to introduce into it any schemes of classification which have not been accepted with tolerable unanimity by naturalists in general. Most or all of the above-mentioned innovations, however, though supported by many and distinguished names, are opposed by others of equal eminence. They may ultimately turn out to be based on nature, but, in the meanwhile, they have not received anything like universal acceptance.

In the second place, most of these proposed changes of classification are founded upon a study of the developmental phenomena of animals. Some highly distinguished zoologists hold that embryological characters will ultimately prove to be the true basis of classification; but in this view the author unfortunately is at present hardly prepared to concur. On the contrary, the author finds himself in the position of being unable to believe that any general system of classification can maintain its ground unless it be based upon the morphological characters exhibited by *adult* animals. He would not be held as denying, or even as depreciating, the importance of embryological studies, but he is unable to believe that the transitory characters of the young animal can have the same general value in classification—for the purposes, at any rate, of ordinary students—as have the characters drawn from the fully developed organism.

In the third place, if the author had here adopted one of the most modern classifications of the animal kingdom, as advocated by those who hold that embryology is the true key to taxonomy, he would have no guarantee that he might not be called upon to fundamentally alter his arrangement within a year or two. For embryologists are not agreed as to the true import of the phenomena of the development of many animals, and some of our highest authorities in this department of investigation deduce diametrically opposite conclusions from their study of the same phenomena.

Lastly, there are cases in which the author has preferred to retain even an antique classification, rather than accept any one of many arrangements which are based upon methods of inquiry, which are of the greatest possible value to the comparative anatomist pure and simple, but which are unavailable for the purposes of those who merely wish to acquire a general but systematic knowledge of Zoology. The class of Birds offers a case in point. In this instance, the author has preferred to retain, with some modifications, an old and only partially natural classification, because the only available substitutes are arrangements which are purely morphological, and which are based upon the observed variations in single structures. Classifications of this kind, though of the utmost use to the genuine comparative anatomist, can never be thoroughly natural, and they are, at any rate, unsuited for any but very advanced students of the science.

In conclusion, the author can only express his regret that the fact that almost the whole of this work had passed through the press before the middle of October last, should have precluded him from in any way availing himself of, or in some cases even from mentioning in the bibliographical lists of references, some highly valuable works of recent appearance, among which the 'Atlantic,' by Sir Wyville Thomson, the 'Morphology of the Skull,' by Professor Parker and Mr Bettany, and Professor Huxley's 'Comparative Anatomy of Invertebrated Animals,' may be specially alluded to.

UNITED COLLEGE, ST ANDREWS,
April 2, 1878.

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MANUAL OF ZOOLOGY.

GENERAL INTRODUCTION.

I. Definition of Biology and Zoology.

Natural History, strictly speaking, and as the term itself implies, should be employed to designate the study of all natural objects indiscriminately, whether these are endowed with life, or exhibit none of those incessant vicissitudes which collectively constitute vitality. So enormous, however, have been the conquests of science within the last century, that Natural History, using the term in its old sense, has of necessity been divided into several more or less nearly related branches.

In the first place, the study of natural objects admits of an obvious separation into two primary sections, of which the first deals with the phenomena presented by the inorganic world, whilst the second is occupied with the investigation of the nature and relations of all bodies which exhibit life. The former department concerns the geologist and mineralogist, and secondarily the naturalist proper as well; the latter department, treating as it does of living beings, is properly designated by the term *Biology* (from *βίος*, *life*, and *λόγος*, a *discourse*). Biology, in turn, may be split up into the sciences of Botany and Zoology, the former dealing with plants, the latter with animals; and it is really *Zoology* alone which is nowadays understood by the term Natural History. It should also be borne in mind that the science which deals with those forms of life which have existed during previous periods of the earth's history to the present, and which is usually designated by the separate title of *Palæontology*, is, in all strictness, part and parcel of *Biology* proper, and has no relations but indirect ones with Geology. As living beings are divisible into animals and plants, so Palæontology falls into the two branches of Palæozoology and Palæobotany, of which the former is inseparably united with Zoology or Natural History, while the latter is part of Botany as ordinarily understood. It is with animals and plants as *organisms* that Palæontology has to deal, and the methods of palæontological inquiry are those employed by the zoologist and the botanist. We must therefore assign to Biology a considerably wider domain than that which has been allowed to it by the earlier workers in the department of Natural History.

It will be obvious, then, that in the attempt to determine the limits and scope of Biology, we are brought at the very threshold of our inquiry to the question, What are the differences between dead and living bodies? Before considering this point, however, it will be advisable to discuss briefly the characters which in a general way distinguish what are known as "organic" from "inorganic" bodies.

2. Differences between Organic and Inorganic Matter.

The terms "organic" and "inorganic," as applied to the various kinds of matter of which the universe is composed, had, to begin with, a very definite signification; the latter being applied to all those forms of matter which exist independently of the operation of living beings, whilst all kinds of matter produced by the vital chemistry of living beings were grouped together under the former title. "Inorganic" Chemistry, for example, was that department of chemical science which dealt with the latter class of bodies; while "Organic" Chemistry concerned itself wholly with those of the former group. Even at an early period, however, some confusion was created by the necessity of employing the term "organic" for accumulations of inorganic matter which had at one time entered into the composition of living beings. Thus, limestone is in one sense inorganic, since carbonate of lime, of which it is formed, occurs in nature quite independently of the operation of living beings. In another sense, however, most limestones are organic, since the lime of which they are composed has been in the main derived from the skeletons of animals or plants.

At the present day, the term "organic" has been widely extended in its significance by the wonderful discoveries of modern science; and "Organic Chemistry," as it is still commonly called, embraces a much more extensive field of investigation than would be afforded merely by those substances which are actually manufactured by living beings. In addition, namely, to substances like starch, sugar, fat, and other bodies which are produced solely by the living organism, and which cannot at present be artificially generated, we embrace under the head of "Organic Chemistry" a vast number of compounds which are not produced by living beings, but are artificially manufactured by the chemist in the laboratory. These compounds are derived by various chemical processes from strictly organic substances, which are in reality the product of vital action, and they might therefore be appropriately called "secondary organic bodies."

The link between the primary and secondary organic bodies is afforded by substances such as *urea*, which is one of the most characteristic of animal products, and which was for a long time unknown except as resulting from animal life. It is now known, however, as first showed by Wöhler, that urea is in chemical composition identical with cyanate of ammonia, a substance which can be manufactured on any desired scale in the laboratory. We may reasonably anticipate that the result of more extensive chemical researches will be very largely to increase the number of bodies which, at present recognised exclusively as the products of vital action, will ultimately be found capable of being artificially manufactured.

It need hardly be added, that the term "organic," as applied to any substance, in no way relates to the presence or absence of *life*. The materials which compose the living body are, of course, "organic" in the main, but they are equally so after death has occurred—at any rate for a certain time—and some of them continue to be so for an indefinite period after life has departed. Sugar, for example, is an organic product; but in itself it is of course dead, and it retains its stability after the organism which produced it has lost all vitality.

The following are the more important characters which distinguish the various organic substances, whether directly produced by living beings, or secondarily formed by chemical processes of different kinds: (1.) Inorganic bodies are composed of a large number of elements; and these elements are either simple and uncombined, or they are associated into simple compounds, which rarely consist of more than two or three elements united, and are therefore called "binary" or "ternary" compounds. On the other hand, organic bodies are composed of few elements, and these are almost always combined. Indeed there are only four principal organic elements—namely, carbon, hydrogen, oxygen, and nitrogen; and of these the first is so much the most important, that Organic Chemistry has been appropriately termed the "Chemistry of Carbon." Furthermore, the combinations of the elements in organic compounds are complex, the resulting substances being mostly "ternary," "quaternary," or "quinary" compounds; and there is generally a larger number of atoms or equivalents of the combining elements than is usually the case among inorganic bodies. Thus, carbonate of lime consists of no more than one atom of calcium, one of carbon, and three of oxygen. On the other hand, albumen, which may be taken as a typical organic substance, consists of 144 atoms of carbon, 110 atoms of hydrogen, 18 atoms of nitrogen, 42 atoms of oxygen, and 2 atoms of sulphur. Hæmoglobin (the red colouring-matter of the blood), again, is stated by Thudichum to consist of no less than 1875 atoms of no more than six elements. Iron, however, exists in the blood, not improbably in its elemental condition; and copper has been detected in the liver of the mammalia, and largely in the red colouring-matter of the feathers of certain birds, in the latter instance being in a condition of loose chemical combination.

(2.) As the result of the large number of atoms which enter into the composition of organic bodies, we find that substances of this class are singularly *unstable*—the stability of all chemical combinations, even amongst inorganic bodies, generally decreasing in direct proportion to the increased number of atoms associated in the compound. Organic bodies, being composed of much larger aggregations of atoms than inorganic, are proportionately more unstable; and this instability is increased by the fact that many organic substances contain nitrogen, an element of feeble and undecided affinities, and also by the fact that all those which are of natural and normal occurrence in the living body, are in this state more or less completely permeated with water.

Hence, the primary organic substances, such as enter directly into the composition of living beings, are so unstable that we usually speak of them as decomposing or breaking up "spontaneously," when removed from the influence of the living organism. So long as they form part of the actually living body, they are to some extent stable, but when removed from this they require nothing more than the presence of oxygen, the existence of moisture, and a moderate degree of warmth, to insure their decomposition. These conditions, though essential, are so universally present, that animal and vegetable matters are generally considered as liable to decay "of themselves." If, however, such substances be deprived of access of air, or be frozen, or have their water driven off by desiccation, they are capable of retaining their chemical composition for an apparently indefinite period of time; and one or other of these conditions is carried out in all processes which have as their end the preservation unchanged of the organic substances which form the bodies of animals and plants.

3. DIFFERENCES BETWEEN DEAD AND LIVING BODIES.

Whilst all living bodies, whether animal or vegetable, are composed essentially of organic substances, there are nevertheless associated with the living organism larger or smaller amounts of matter which is practically dead. On the other hand there are numerous secondary organic products which at no time enter into the composition of living bodies, and which are therefore just as much "dead" substances as the genuine inorganic substances.

The general distinctions between dead and living matter are the following:—

a. Mode of Increase.—Living bodies possess the power of taking into their interior certain materials (food), foreign to those composing their own substance, and of converting these into the materials of which they are themselves built up. This process is known as "assimilation," and it is in virtue of this that living bodies *grow*. The growth of the organism, therefore, and its increase in size, is not effected by the mere addition of matter from the outside, but by the taking of matter into the interior of the body, and its modification there.

On the other hand, when dead bodies increase in size (as crystals do in supersaturated solutions), this is effected simply by the addition of particles from the outside, or, as it is technically called, by the "accretion," instead of by the "intussusception," of matter. The newly added particles undergo no change from their previous constitution, and the essential element of "assimilation" is thus wanting, so that the process is in no sense one of "growth" properly so called.

b. Cyclical Change.—All dead matter tends to assume a condition of permanent stability and repose. Living matter, on the other hand, is pre-eminently distinguished by its tendency to pass through a series of cyclical changes, all the actions of living bodies being accompanied by a corresponding destruction of the matter by which these actions are effected. All these cyclical changes are effected by the slow but incessant reduction of the living matter of the organism to the non-living condition. Active life, therefore, can only be carried on by the constant destruction of portions of the living matter of the body; and to meet the loss thus caused, it is necessary that a corresponding amount of non-living matter should be constantly "assimilated," and raised from the statical condition of dead matter to the dynamical condition of living matter.

c. Relations to the outside World.—Dead bodies are subject to the physical and chemical forces of the universe, and have no power of suspending these forces, or modifying their action, even for a limited period. On the other hand, living bodies, whilst subject to the same forces, are the seat of something in virtue of which they can override, suspend, or modify the actions of the physical and chemical forces by which dead bodies are exclusively governed. Dead matter is completely passive, unable to originate motion, and equally unable to arrest it when once originated. Living matter, so long as it *is* living, is the seat of *energy*, and can overcome the primary law of the *inertia* of matter. However humble it may be, and even if permanently rooted to one place, every living body possesses, in some part or other, or at some period of its existence, the power of independent and spontaneous movement—a power possessed by nothing that is dead. Similarly, the chemical forces, which work unresisted amongst the particles of dead matter, are in the living organism directed harmoniously to given ends, their action regulated under definite laws, and their natural working often strikingly modified, or even temporarily suspended, and this as effectually and as perfectly in the humblest as in the highest of created beings.

As a result of this, dead bodies exhibit nothing but *reactions*, and these purely of a physical and chemical nature, whilst they show no tendency to pass through periodical changes of state. On the other hand, living bodies exhibit distinct *actions*, and are pre-eminently characterised by their tendency to pass through a series of cyclical changes, which follow one another in a regular and determinate sequence.

d. Reproduction.—Every living body has the power of reproducing its like. Directly or indirectly, every living body has the power of giving off minute portions of its own substance, which, under proper conditions, will be developed into the likeness of the parent.

4. NATURE AND CONDITIONS OF LIFE.

Life has been variously defined by different writers. Bichat defines it as "the sum total of the functions which resist death;" Treviranus, as "the constant uniformity of phenomena with diversity of external influences;" Duges, as "the special activity of organised bodies;" and Beclard, as "organisation in action." All these definitions, however, are more or less objectionable, since they either really mean nothing, or the assumption underlies them that life is inseparably connected with organisation. In point of fact, no rigid definition of life appears to be at present possible, and it is best to regard it as being simply a tendency exhibited by certain forms of matter, under certain conditions, to pass through a series of changes in a more or less definite and determinate sequence. The essential phenomenon of vitality is, therefore, in the words of Herbert Spencer, "the continuous adjustment of internal relations to external relations," and life, in its *effect*, is the totality of the functions of a living being. Life, however, may also be considered as a *cause*, since amongst the phenomena presented by all living beings there are some which cannot be referred to the action of known physical or chemical laws, and which, therefore, temporarily at any rate, we must term "vital."

Whilst the nature of life thus does not admit of rigid definition, we find that the phenomena of vitality can only be manifested under certain *conditions*, some of these being *intrinsic* and indispensable, whilst others are *extrinsic*, and not in themselves, or collectively, essential.

The only intrinsic condition of life appears to be the existence of a special "*physical basis*," as it has been termed. We do not find, namely, that the phenomena of vitality can be manifested by any and every form of matter. On the contrary, and as might have been expected upon *a priori* grounds, all living bodies appear to be composed of a special substance, which is the material basis of life, and which seems to be substantially identical in all alike. No living body is throughout composed of this living basis, but all contain a greater or smaller amount of other materials, which are in one sense dead. The real phenomena of vitality are conditioned, therefore, by certain special portions of the organism, which are alone formed of this living matter; and this matter in chemical composition and physical characters appears to be identical in all living beings whether animal or vegetable. To this physical basis the names of "protoplasm" or "bioplasm" are applied. The lowest organisms consist of little else but simple unmodified protoplasm; but even in the most complex organisms it can be shown that their essential parts, in which alone vitality is inherent, are similarly composed of protoplasmic matter.

As regards its nature, protoplasm, though capable of forming the most complex structures, does not necessarily exhibit anything which can be looked upon as organisation, or differentiation into distinct parts; and its chemical composition is the only constant which can be approximately stated. It consists, namely, in all its forms, of the four elements, carbon, hydrogen, oxygen, and nitrogen, united into a proximate compound to which Mulder applied the name of "proteine," and which is very nearly identical with albumen or white-of-egg. It further appears probable that all forms of protoplasm can be made to contract by means of electricity, and "are liable to undergo that peculiar coagulation at a temperature of 40°-50° centigrade, which has been called 'heat-stiffening'" (Huxley). As viewed under the microscope, protoplasm presents itself as a clear viscous, semi-fluid substance, which is commonly rendered granular by the presence of disseminated particles of fatty matter, and which is deeply stained by immersion in a solution of carmine.

In addition to the physical and chemical properties of protoplasm, many writers are in the habit of speaking of the "vital properties" of this substance. These so-called "vital properties" are necessarily the same as those manifested by living beings in general, and consist in the power exhibited by living protoplasm of assimilating foreign matter, of reproducing itself by the detachment of portions of its substance, and of having certain relations with the world outside itself. As regards the last of these points, protoplasm, in its living state, when unconfined by any rigid wall or outer envelope, possesses the power of throwing out longer or shorter prolongations or processes of its own substance ("pseudopodia"), by means of which it can obtain food, or, if free, move about. Even in vegetable cells, where a rigid cell-wall is as a rule present, the protoplasm in the interior is often capable of rotation as a whole, or of exhibiting an active circulation of granules similar to that observed in many masses of animal protoplasm. Moreover, the researches of Mr Francis Darwin have shown that the cells of the glandular hairs of the Common Teasel (*Dipsacus sylvestris*) emit mobile filaments of protoplasm quite similar to the "pseudopodia" of many of the lower animals; while wall-less masses of protoplasm, capable of emitting pseudopodia, are met with in the life-history of some of the lower plants.

In speaking, however, of the power of nutrition and reproduction, or of the power of emitting pseudopodia, or of exhibiting irritability as being "vital properties" of protoplasm, a fallacious mode of reasoning is employed. These powers belong to *living* protoplasm, and it remains to be shown that they are even potentially present in dead protoplasm—as protoplasm. At any rate, they stand in a different category to the physical and chemical "properties" of protoplasm, since we must suppose these to be invariably and constantly present in protoplasm, whether alive or dead; unless we are to deny that protoplasm is a definite compound at all.

Apart from this, however, we may admit that protoplasmic matter* is "the formal basis of all life" (Huxley); and that the phenomena of vitality cannot be manifested save through the vehicle of protoplasm. Nevertheless, there remain certain conditions equally indispensable to the external manifestation of vital phenomena; though life itself, or the *power* of exhibiting vital phenomena, may be preserved for a longer or shorter period, even though these conditions be absent. These *extrinsic* conditions of vitality are, *firstly*, a certain temperature varying from near the freezing-point to 120° or 130°; *secondly*, the presence of water, which enters largely into the composition of all living tissues; *thirdly*, the presence of oxygen in a free state, though some of the lower forms of vegetable life are capable of existing in an atmosphere devoid of oxygen.

The higher manifestations of life are not, as a general rule, possible unless all the extrinsic conditions just mentioned are carried out, and the non-fulfilment of any of them generally causes *death;* but there are some notable exceptions to this statement. Thus, life may remain in a dormant or "potential" condition for an apparently indefinite time, as exhibited by the great tenacity of life, even under unfavourable circumstances, exhibited by the ova of some animals and the seeds of many plants. A still more striking example of this is afforded by the minute microscopic animals known as the Rotifers or Wheel-animalcules. These little creatures are aquatic in their habits; and diminutive as they are, they are, nevertheless, comparatively speaking, of a very high grade of organisation. They possess a mouth, masticatory organs, a stomach and alimentary canal, a distinct and well-developed nervous system, a differentiated reproductive apparatus, and even organs of vision. Repeated experiments, however, have shown the remarkable fact that, with their aquatic habits and complex organisation, the Rotifers are capable of submitting to an apparently indefinite deprivation of the necessary conditions of their existence, without thereby losing their vitality. They may be dried and reduced to all appearance to dust, and may be kept in this state for a period of years; nevertheless, the addition of a little water will at any time restore them to their pristine vigour and activity. It follows, therefore, that an organism may be deprived of all power of manifesting any of the phenomena which constitute what we call life, without losing its hold upon the vital forces which belong to it.

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* It has not yet been shown that the living matter which we designate by the convenient term of "protoplasm" has universally and in all cases a constant and undeviating chemical composition; and there is, indeed, reason to believe that this is not the case. It is also certain that there are other materials, the exact use of which we do not at present know, which are absolutely essential to the maintenance of life, probably even in its humblest manifestations.

Again, the vital resistance of the lowest organisms to changes of temperature, seems to be in some cases much wider than that stated above as generally true. Thus, the microscopic organisms known as "vibrios" are stated to survive exposure to a temperature of 300° F., and to be wholly unaffected by being frozen; whilst Dallinger and Drysdale have shown that the germs of monads will survive exposure to temperatures of from 280° to 300° F. The presence of oxygen in a free state, too, though essential to the higher forms of life, does not appear to be necessary in the case of some of the lower; since vibrios and bacteria appear to carry on a vigorous life in an atmosphere of carbonic acid gas. Lastly, there are certain conditions, such as the presence of sun-light, which are essential for the maintenance of life *as a whole,* though by no means necessarily demanded for the life of individuals. Thus, vegetable life is as a whole dependent upon sun-light, and though animals can subsist in darkness, animal life is in reality dependent upon plant-life, so that the total absence of the sun would extinguish all life whatever.

The only other condition of life which need be noticed is the presence of "organisation" in living bodies; and the importance of this has been greatly reduced by the progress of modern science. All the higher forms of life are "organised," —that is to say, they possess distinct parts or "organs," which have certain definite relations to one another, and which discharge certain definite offices or "functions." The protoplasmic and actually living portions even of these, however, appear, under the highest powers of the microscope, to be destitute of any recognisable *structure*, and are therefore not "organised." Moreover, many of the lowest forms of life (such as the Foraminifera amongst the Protozoa) fail to fulfil one of the most essential conditions of organisation, being mostly or wholly devoid of definite parts or organs. Nevertheless, they are capable of manifesting all the essential phenomena of life; they are produced from bodies like themselves; they eat, digest, and move, and exhibit distinct sensibility to many external impressions. Furthermore, many of these little masses of structureless jelly possess the power of manufacturing for themselves, of lime, or of the still more intractable flint, external shells of surpassing beauty and mathematical regularity. In the face of these facts we are therefore compelled to come to the conclusion that life is really the *cause* and not the consequence of organisation; or, in other words, that organisation is not an intrinsic and indispensable condition of vital phenomena. While it is generally admitted that "organisation," in the ordinary acceptation of this term, is not essential to the manifestation of vitality, there are high authorities who consider that the great differences in the vital phenomena of different organisms are due to differences in the "molecular complexity" of the protoplasm forming the bodies of these. Apart, however, from the fact that such differences in "molecular complexity" are, and must remain, hypothetical, this view can hardly be regarded otherwise than as a revival, in another form, of the theory that vital phenomena are the result of the organisation of the living body; since "molecular complexity" is only "organisation," with the "organs" so minute as to evade the highest powers of the microscope.

As to the precise relations which subsist between the "physical basis of life" and the phenomena of vitality, it is held by some that "life" is one of the *properties* of the albuminous body which we term protoplasm. On this view, life is a form of energy or motion, due simply to molecular movements taking place in the ultimate molecules of the protoplasm, and capable of correlation with the ordinary physical or chemical forces. It cannot, however, be said that this view has as yet received a scientific demonstration. On the other hand, it seems safer, with our present knowledge, to believe that protoplasm is simply the necessary material basis or *vehicle* through which vital force is manifested, though we are still unable to speak with any positiveness as to the precise nature of the forces which are the fundamental causes of life.

If, in conclusion, it be asked whether the term "vital force" is any longer permissible in the mouth of a scientific man, the question must, in the meanwhile, be answered in the affirmative. Formerly, no doubt, the progress of science was retarded and its growth checked by a too exclusive reference of natural phenomena to a so-called vital force. Equally unquestionable is the fact that the development of biological science has progressed contemporaneously with the successive victories gained by the physicists over the vitalists. Still, no physicist has hitherto succeeded in explaining any fundamental vital phenomenon upon purely physical and chemical principles. The simplest vital phenomenon has in it something over and above the merely chemical and physical forces which we can demonstrate in the laboratory. It is easy, for example, to say that the action of the gastric juice is a chemical one, and doubtless the discovery of this fact was a great step in physiological science. Nevertheless, in spite of the most searching investigations, it is certain that digestion presents phenomena which are as yet inexplicable upon any chemical theory. This is exemplified in its most striking form, when we look at a simple organism like the Amœba. This animalcule, which is structurally little more than a mobile lump of semi-fluid protoplasm, digests as perfectly—as far as the result to itself is concerned—as does the most highly organised animal with the most complex digestive apparatus. It takes food into its interior, it digests it without the presence of a single organ for the purpose; and, still more, it possesses that inexplicable selective power by which it assimilates out of its food such constituents as it needs, whilst it rejects the remainder. In the present state of our knowledge, therefore, we must conclude that even in the process of digestion, as exhibited in the Amœba, there is something that is not merely physical or chemical. Similarly, any organism when just dead, consists of the same protoplasm as before, in the same forms, and with the same arrangement; but it has most unquestionably lost a something by which all its properties and actions were modified, and some of them were produced. What that something is, we do not know, and perhaps never shall know; and it is possible, though highly improbable, that future discoveries may demonstrate that it is merely a subtle modification of some physical force. In the meantime, as all vital actions exhibit this mysterious something, it would appear unphilosophical to ignore its existence altogether, and the term "vital force" may therefore be retained with advantage. In using this term, however, it must not be forgotten that we are simply employing a convenient expression for an unknown quantity, for that residual portion of every vital action which cannot at present be referred to the operation of any known physical force.

It must, however, also be borne in mind that this residuum is probably not to be ascribed to our ignorance, but that it has a real existence. It appears, namely, in the highest degree probable that every vital action has in it something which is not merely physical and chemical, but which is conditioned by an unknown force, higher in its nature and distinct in kind as compared with all other forces. The presence of this "vital force" may be recognised even in the simplest phenomena of nutrition; and no attempt even has hitherto been made to explain the phenomena of reproduction by the working of any known physical or chemical force.

5. Differences between Animals and Plants.

We have now arrived at some definite notion of the essential characters of living beings in general, and we have next to consider what are the characteristics of the two great divisions of the organic world. What are the characters which induce us to place any given organism in either the vegetable or the animal kingdom? What, in fact, are the differences between animals and plants?

It is generally admitted that all bodies which exhibit vital phenomena are capable of being referred to one of the two great kingdoms of organic nature. At the same time it is often extremely difficult in individual cases to come to any decision as to the kingdom to which a given organism should be referred, and in many cases the determination is purely arbitrary. So strongly, in fact, has this difficulty been felt, that some observers have established an intermediate kingdom, a sort of no-man's-land for the reception of those debatable organisms which cannot be definitely and positively classed either amongst vegetables or amongst animals. Thus, Dr Ernst Hæckel has proposed to form an intermediate kingdom, which he calls the *Regnum Protisticum*, for the reception of all doubtful organisms. Even such a cautious observer as Dr Rolleston, whilst questioning the propriety of this step, is forced to conclude that "there are organisms which at one period of their life exhibit an aggregate of phenomena such as to justify us in speaking of them as animals, whilst at another they appear to be as distinctly vegetable."

In the case of the higher animals and plants, there is no difficulty; the former being at once distinguished by the possession of a nervous system, of motor power which can be voluntarily exercised, and of an internal cavity fitted for the reception and digestion of solid food. The higher plants, on the other hand, possess no nervous system or organs of sense, are incapable of independent locomotion, and are not provided with an internal digestive cavity, their food being wholly fluid or gaseous. These distinctions, however, do not hold good as regards the lower and less highly organised members of the two kingdoms, many animals having no nervous system or internal digestive cavity, whilst many plants possess the power of locomotion; so that we are compelled to institute a closer comparison in the case of these lower forms of life.

a. Form.—As regards external configuration, of all characters the most obvious, it must be admitted that no absolute distinction can be laid down between plants and animals. Many of our ordinary zoophytes, such as the Hydroid Polypes, the Sea-shrubs and Corals—as, indeed, the name zoophyte implies—are so similar in external appearance to plants that they were long described as such. Amongst the Molluscoida, the Common Sea-mat (Flustra) is invariably regarded by seaside visitors as a sea-weed. Many of the Protozoa are equally like some of the lower plants (Protophyta); and even at the present day there are not wanting those who look upon the sponges as belonging to the vegetable kingdom. On the other hand, the embryonic forms, or "zoöspores," (fig. 1, *a* and *b*) of certain undoubted plants (such as the Protococcus nivalis, Vaucheria, &c.), are provided with ciliated processes with which they swim about, thus coming so closely to resemble some of the Infusorian animalcules as to have been referred to that division of the Protozoa.

b. Internal Structure.—Here, again, no line of demarcation can be drawn between the animal and vegetable kingdoms. In this respect all plants and animals are fundamentally similar, being alike composed of molecular, cellular, and fibrous tissues.

c. Chemical Composition.—Plants, speaking generally, exhibit a preponderance of ternary compounds of carbon, hydrogen, and oxygen—such as starch, cellulose, and sugar—whilst nitrogenised compounds enter more largely into the composition of animals. Still both kingdoms contain identical or representative compounds, though there may be a difference in the proportion of these to one another. Moreover, the most characteristic of all vegetable compounds—viz., cellulose—has been detected in the outer covering of the Sea-squirts, or Ascidian Molluscs; and the so-called "glycogen," which is secreted by the liver of the Mammalia, is closely allied to, if not absolutely identical with, the hydrated starch of plants. As a general rule, however, it may be stated that the presence in any organism of an external envelope of cellulose raises a strong presumption of its vegetable nature. In the face, however, of the facts above stated, the presence of cellulose cannot be looked upon as absolutely conclusive. Another highly characteristic vegetable compound is *chlorophyll*, the green colouring-matter of plants. Any organism which exhibits chlorophyll in any quantity, as a proper element of its tissues, is most probably vegetable. As in the case of cellulose, however, the presence of chlorophyll cannot be looked upon as a certain test, since it occurs normally in certain un-

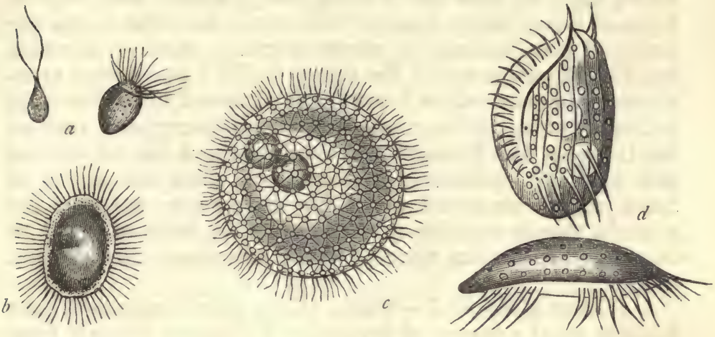

Fig. 1.—Algæ and Infusoria. *a* Ciliated zoöspores of *Confervæ; b* Ciliated zoöspore of *Vaucheria; c Volvox globator,* a locomotive fresh-water plant; *d Euplotes charon,* one of the *Infusoria.* All greatly magnified.

doubted animals (*e.g.*, *Stentor*, amongst the *Infusoria*, and the *Hydra viridis*, or the green Fresh-water Polype, amongst the *Cœlenterata*).

d. Motor Power.—This, though broadly distinctive of animals, can by no means be said to be characteristic of them. Thus, many animals in their mature condition are permanently fixed, or attached to some foreign object; and the embryos of many plants, together with not a few adult forms, are endowed with locomotive power by means of those vibratile, hair-like processes which are called "cilia," and are so characteristic of many of the lower forms of animal life. Not only is this the case, but large numbers of the lower plants, such as the Diatoms and Desmids, exhibit throughout life an amount and kind of locomotive power which does not admit of being rigidly separated from the movements executed by animals, though the closest researches have hitherto failed to show the mechanism whereby these movements are brought about.

e. Nature of the Food.—Whilst all the preceding points have failed to yield a means of invariably separating animals from plants, a distinction which holds good almost without exception is to be found in the nature of the food taken respectively by each, and in the results of the conversion of the same. The unsatisfactory feature, however, in this distinction is this, that even if it could be shown to be, theoretically, invariably true, it would nevertheless be practically impossible to apply it to the greater number of those minute organisms concerning which alone there can be any dispute.

As a broad rule, all plants are endowed with the power of converting inorganic into organic matter. The *food* of plants consists of the inorganic compounds, carbonic acid, ammonia, and water, along with small quantities of certain mineral salts. From these, and from these only, plants are capable of elaborating the proteinaceous matter or protoplasm which constitutes the physical basis of life. Plants, therefore, take as food very simple bodies, and manufacture them into much more complex substances. In other words, by a process of deoxidation or unburning, rendered possible by the influence of sunlight only, plants convert the inorganic or stable elements—ammonia, carbonic acid, water, and certain mineral salts—into the organic or unstable elements of food. The whole problem of nutrition may be narrowed to the question as to the modes and laws by which these stable elements are raised by the vital chemistry of the plant to the height of unstable compounds.

To this general statement, however, an exception must be made in favour of certain Fungi, which require ready-made organic matter for their nourishment. There are also certain plants (such as the Sun-dew and the Venus' Fly-trap) which live to some extent upon animal food.

On the other hand, no known animal possesses the power of converting inorganic compounds into organic matter, but all, mediately or immediately, are dependent in this respect upon plants. All animals, as far as is certainly known, require ready-made proteinaceous matter for the maintenance of existence, and this they can only obtain in the first instance from plants. Animals, in fact, differ from plants in requiring as food complex organic bodies which they ultimately reduce to very much simpler inorganic bodies. The nutrition of animals is a process of oxidation or burning, and consists essentially in the conversion of the energy of the food into vital work; this conversion being effected by the passage of the food into living tissue. Plants, therefore, are the great manufacturers in nature, —animals are the great consumers.

There remain to be noticed two distinctions, broadly though not universally applicable, which are due to the nature of the food required respectively by animals and plants. In the first place, the food of all plants consists partly of gaseous matter, and partly of matter held in solution. They require, therefore, no special aperture for its admission, and no internal cavity for its reception. The food of almost all animals consists of solid particles, and they are therefore usually provided with a mouth and a distinct digestive cavity. Some animals, however, such as the tapeworms and the Gregarinæ, live entirely by the imbibition of organic fluids through the general surface of the body, and many have neither a distinct mouth nor stomach.

Secondly, plants decompose carbonic acid, retaining the carbon and setting free the oxygen, certain fungi forming an exception to this law. The reaction of plants upon the atmosphere is therefore characterised by the production of free oxygen. Animals, on the other hand, absorb oxygen and emit carbonic acid, so that their reaction upon the atmosphere is the reverse of that of plants, and is characterised by the production of carbonic acid.

Finally, it is worthy of notice that it is in their lower and not in their higher developments that the two kingdoms of organic nature approach one another. No difficulty is experienced in separating the higher animals from the higher plants, and, for these, universal laws can be laid down to which there is no exception. It might, not unnaturally, have been thought that the lowest classes of animals would exhibit most affinity to the highest plants, and that thus a gradual passage between the two kingdoms would be established. This is not the case, however. The lower animals are not allied to the higher plants, but to the lower; and it is in the very lowest members of the vegetable kingdom, or in the embryonic and immature forms of plants little higher in the scale, that we find such a decided animal gift as the power of independent locomotion. It is also in the less highly organised and less specialised forms of plants that we find

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the chief departures from the great laws of vegetable life, the deviation being in the direction of the laws of animal life.

6. Morphology and Physiology.

The next point which demands notice relates to the nature of the differences between one animal and another, and the question is one of the highest importance. Every animal—as every plant—may be regarded from two totally distinct, and, indeed, often apparently opposite, points of view. From the first point of view we have to look simply to the laws, form, and arrangement of the *structures* of the organism; in short, to its external shape and internal structure. This constitutes the science of morphology (*μορφή*, *form*, and λόγος, *discourse*). From the second, we have to study the vital actions performed by living beings and the *functions* discharged by the different parts of the organism. This constitutes the science of physiology.

A third department of zoology is concerned with the relations of the organism to the external conditions under which it is placed, constituting a division of the science to which the term "distribution" is applied.

Morphology, again, not only treats of the structure of living beings in their fully-developed condition (anatomy), but is also concerned with the changes through which every living being has to pass before it assumes its mature or adult characters (embryology or development). The term "histology" is further employed to designate that branch of morphology which is specially occupied with the investigation of minute or microscopical tissues.

Physiology treats of all the functions exercised by living bodies, or by the various definite parts or organs, of which most animals are composed. All these functions come under three heads:—1. *Functions of Nutrition*, divisible into functions of absorption and metamorphosis, comprising those functions which are necessary for the growth and maintenance of the organism. 2. *Functions of Reproduction*, whereby the perpetuation of the species is secured. 3. *Functions of Correlation*, comprising all those functions (such as sensation and voluntary motion) by which the external world is brought into relation with the organism, and the organism in turn reacts upon the external world.

Of these three, the functions of nutrition and reproduction are often collectively called the functions of organic or vegetative life, as being common to animals and plants; while the functions of correlation are called the animal functions, as being more especially characteristic of, though not peculiar to, animals.

7. Differences between different Animals.

All the innumerable differences which subsist between different animals may be classed under two heads, corresponding to the two aspects of every living being, morphological and physiological. One animal differs from another either *morphologically*, in the fundamental points of its structure; or *physiologically*, in the manner in which the vital functions of the organism are discharged. These constitute the only modes in which any one animal can differ from any other; and they may be considered respectively under the heads of Specialisation of Function and Morphological type.

a. Specialisation of Function.—All animals alike, whatever their structure may be, perform the three great physiological functions; that is to say, they all nourish themselves, reproduce their like, and have certain relations with the external world. They differ from one another physiologically in the *manner* in which these functions are performed. Indeed, it is only in the functions of correlation that it is possible that there should be any difference in the amount or perfection of the function performed by the organism, since nutrition and reproduction, as far as their results are concerned, are essentially the same in all animals. In the manner, however, in which the same results are brought about, great differences are observable in different animals. The nutrition of such a simple organism as the Amœba is, indeed, performed perfectly, as far as the result to the animal itself is concerned—as perfectly as in the case of the highest animal—but it is performed with the simplest possible apparatus. It may, in fact, be said to be performed without any *special* apparatus, since any part of the surface of the body may be extemporised into a mouth, and there is no differentiated alimentary cavity. And not only is the nutritive apparatus of the simplest character, but the function itself is equally simple, and is entirely divested of those complexities and separations into secondary functions which characterise the process in the higher animals. It is the same, too, with the functions of reproduction and correlation; but this point will be more clearly brought out if we examine the method in which one of the three primary functions is performed in two or three examples. Nutrition, as the simplest of the functions, will best answer the purpose.

In the simpler Protozoa, such as the Amœba, the process of nutrition consists essentially in the reception of food, its digestion within the body, the excretion of effete or indigestible matter, and the distribution of the nutritive fluid through the body. The first three portions of this process are effected without any special organs for the purpose, and for the last there is simply a rudimentary contractile cavity. Respiration, if it can be said to exist at all as a distinct function, is simply effected by the general surface of the body.

In a Cœlenterate animal, such as a sea-anemone, the function of nutrition has not advanced much in complexity, but the means for its performance are somewhat more specialised. Permanent organs of prehension (tentacles) are present, there is a distinct mouth, and there is a persistent internal cavity for the reception of the food; but this is not shut off from the general cavity of the body, and there are no distinct circulatory or respiratory organs.

In a Mollusc, such as the oyster, nutrition is a much more complicated process. There is a distinct mouth, and an alimentary canal which is shut off from the general cavity of the body, and is provided with a separate aperture for the excretion of effete and indigestible matters. Digestion is performed by a distinct stomach with accessory glands; a special contractile cavity, or heart, is provided for the propulsion of the nutritive products of digestion through all parts of the organism; and the function of respiration is performed by complex organs specially adapted for the purpose.

It is not necessary here to follow out this comparison further. In still higher animals the function of nutrition becomes still further broken up into secondary functions, for the due performance of which special organs are provided, the complexity of the organism thus necessarily increasing *pari passu* with the complexity of the function. This gradual subdivision and elaboration is carried out equally with the other two physiological functions—viz., reproduction and correlation —and it constitutes what is technically called the "specialisation of function," though it has been more happily termed by Milne-Edwards "the principle of the physiological division of labour." It is needless, however, to remark that in the higher animals it is the functions of correlation which become most highly specialised—disproportionately so, indeed, when compared with the development of the nutritive and reproductive functions.

b. Morphological Type. — The first point in which one animal may differ from another is the degree to which the principle of the physiological division of labour is carried. The second point in which one animal may differ from another is in its "morphological type;" that is to say, in the fundamental plan upon which it is constructed. By one not specially acquainted with the subject it might be readily imagined that each species or kind of animal was constructed upon a plan peculiar to itself and not shared by any other. This, however, is far from being the case; and it is now universally recognised that all the varied species of animals—however great the apparent amount of diversity amongst them—may be arranged under no more than half-a-dozen primary morphological types or plans of structure. Upon one or other of these six (or perhaps seven) plans every known animal, whether living or extinct, is constructed. It follows from the limited number of primitive types or patterns, that great numbers of animals must agree with one another in their morphological type. It follows, also, that all so agreeing can differ from one another only in the sole remaining element of the question—namely, by the amount of specialisation of function which they exhibit. Every animal, therefore, as Professor Huxley has well expressed it, is the resultant of two tendencies, the one morphological, the other physiological.

The six types or plans of structure, upon one or other of which all known animals have been constructed, are technically called "sub-kingdoms," and are known by the names Protozoa, Cœlenterata, Echinodermata, Annulosa, Mollusca, and Vertebrata. We have, then, to remember that every member of each of these primary divisions of the animal kingdom agrees with every other member of the same division in being formed upon a certain definite plan or type of structure, and differs from every other simply in the grade of its organisation, or, in other words, in the degree to which it exhibits specialisation of function.

VON BAER'S LAW OF DEVELOPMENT.—As the study of living beings in their adult condition shows us that the differences between those which are constructed upon the same morphological type depend upon the degree to which specialisation of function is carried, so the study of development teaches us that the changes undergone by any animal in passing from the embryonic to the mature condition are due to the same cause. All the members of any given sub-kingdom, when examined in their earliest embryonic condition, are found to present the same fundamental characters. As development proceeds, however, they diverge from one another with greater or less rapidity, until the adults ultimately become more or less different, the range of possible modification being apparently almost illimitable. The differences are due to the different degrees of specialisation of function necessary to perfect the adult; and therefore, as Von Baer put it, *the progress of development is from the general to the special.*

It is upon a misconception of the true import of this law that the theory arose, that every animal in its development passed through a series of stages in which it resembles, in turn, the different inferior members of the animal scale. With regard to man, standing at the top of the whole animal kingdom, this theory has been expressed as follows: "Human organogenesis is a transitory comparative anatomy, as, in its turn, comparative anatomy is a fixed and permanent state of the organogenesis of man" (Serres). In other words, the embryo of a Vertebrate animal was believed to pass through a series of changes corresponding respectively to the permanent types of the lower sub-kingdoms—namely, the Protozoa, Cœlenterata, Echinodermata, Annulosa, and Mollusca—before finally assuming the true vertebrate characters. Such, however, is not truly the case. The ovum of every animal is from the first impressed with the power of developing in one direction only, and very early exhibits the fundamental characters proper to its sub-kingdom, never presenting the structural peculiarities belonging to any other morphological type. Nevertheless, the differences which subsist between the members of each sub-kingdom in their adult condition are truly referable to the degree to which development proceeds, the place of each individual in his own sub-kingdom being regulated by the stage at which development is arrested. Thus, many cases are known in which the younger stages of a given animal *represent* the permanent adult condition of an animal somewhat lower in the scale. To give a single example, the young Gasteropod (amongst the Mollusca) transiently presents all the essential characters which permanently distinguish the adult Pteropod. The development of the Gasteropod, however, proceeds beyond this point, and the adult is much more highly specialised than is the adult Pteropod.

The theory of development held by the supporters of the doctrine of Evolution is best expressed in the words of Prof. Hæckel. According to this eminent naturalist, "Ontogenesis" (or the development of the individual) "is the brief and rapid recapitulation of phylogenesis" (or the development of the species) "governed by the physiological functions of transmission (reproduction) and nutrition (adaptation). The organic individual, during the rapid and brief course of its individual development, repeats the most important of those changes of form which its ancestors have passed through during the long and gradual course of their palæontological development, in accordance with the laws of transmission and adaptation."

8. HOMOLOGY, ANALOGY, AND HOMOMORPHISM.

When organs in different animals agree with one another in fundamental *structure*, they are said to be "homologous;" when they perform the same functions they are said to be "analogous." Thus the wing of a bird and the arm of a man are constructed upon the same fundamental plan, and they are therefore homologous organs. They are not analogous, however, since they do not perform the same function, the one being adapted for aerial locomotion, the other being an organ of prehension. On the other hand, the wings of a bird and the wings of an insect both serve for flight, and they are therefore analogous, since they perform the same function. They are not homologous, however, as they are constructed upon wholly dissimilar plans. There are numerous cases, however, in which organs correspond with one another both structurally and functionally, in which case they are both homologous and analogous.

A form of homology is often seen in a single animal in which there exists a succession of parts which are fundamentally identical in structure, but are variously modified to fulfil different functions. Thus a Crustacean—such as the lobster—may be looked upon as being composed of a succession of rings, each of which bears a pair of appendages, these appendages being constructed upon the same type, and being therefore homologous. They are, however, variously modified in different regions of the body to enable them to fulfil special functions, some being adapted for swimming, others for walking, others for prehension, others for mastication, and so on. This succession of fundamentally similar parts in the same animal constitutes what is known as *serial homology*. When, however, the successive parts are similar to one another, both in structure and in function, the case becomes rather one of what is called "vegetative" or "irrelative repetition." An excellent instance of this is seen in the common Millipede (Iulus).

Homomorphism.—Many examples occur, both among animals and among plants, in which families widely removed from one another as to their fundamental structure, nevertheless present a singular, and sometimes extremely close, resemblance in their external characters. Thus the composite Hydroid

Zoophytes and the Polyzoa are singularly like one another—so much so, that they have often been classed together; whereas, in reality, they belong to different sub-kingdoms. Many other cases of this resemblance of different animals might be adduced, and in many cases these "representative forms" appear to be able to fill each other's places in the general economy of nature. This is so far true, at any rate, that "homomorphous" forms are generally found in different parts of the earth's surface. Thus, the place of the Cacti of South America is taken by the Euphorbiæ of Africa; or, to take a zoological illustration, many of the different orders of Mammalia are *represented* in the single order Marsupialia in Australia, in which country this order has almost alone to discharge the functions elsewhere performed by several orders. Many homomorphous forms, however, live peacefully side by side, and it is difficult to say whether in this case the resemblance between them is for the advantage or for the disadvantage of either. In other cases we find certain animals putting on the external characters of certain other animals, to which they may be closely related, or from which they may be widely separated in zoological position. Such cases are said to be examples of "mimicry," and such animals are said to be "mimetic." Excellent examples of this may be found amongst certain Butterflies, or in the close resemblance of the clear-winged Moths to Bees and Hornets. In all these cases it appears that the mimetic species is protected from some enemy by its outward similarity to the form which it mimics. Finally, there are numerous cases in which animals resemble certain natural objects, and thus greatly diminish their chances of being detected by their natural foes. Excellent instances of this "protective resemblance" are afforded by the insects known as Walking-leaves (*Phyllium*, fig. 2) and Walking-sticks (*Phasmidæ*), which respectively present the most singular resemblance to leaves and dried twigs. The student, however, must carefully guard himself against supposing that the term "mimicry" implies any *conscious* action on the part of the mimetic species; there being no evidence to support such a view.

9. CORRELATION OF GROWTH.

This term is employed by zoologists to express the empirical law, that certain structures, not necessarily or usually connected together by any visible link, invariably occur in association with one another, and never occur apart—so far, at any rate, as human observation goes.

Thus, all animals which possess two condyles on the occipital bone, and possess non-nucleated red blood-corpuscles, suckle their young. Why an animal with only one condyle on its occipital bone should not suckle its young we do not know, and perhaps we shall at some future time find mammary glands associated with a single occipital condyle. Most of these correlations are physiologically difficult of explanation, and sometimes even amusing. Thus all, or almost all, male cats, which are entirely white and have blue eyes, are at the same time deaf. With regard to these and similar generalisations we must, however, bear in mind the following three points :—

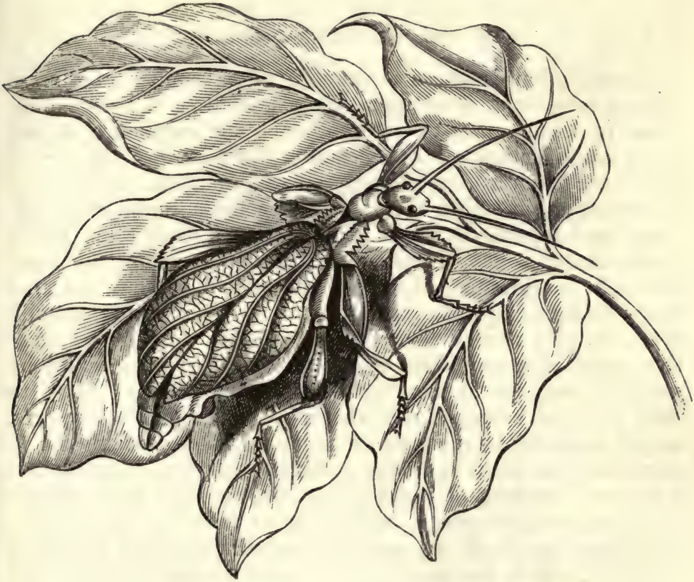

Fig. 2.—Walking-Leaf Insect (*Phyllium*).

1. The various parts of the organisation of any animal are so closely interconnected, and so mutually dependent upon one another, both in their growth and development, that the characters of each must be in *some* relation to the characters of all the rest, whether this be obviously the case or not.

2. It is rarely possible to assign any reason for correlations of structure, though they are certainly in no case accidental.

3. The law is a purely empirical one, and expresses nothing more than the result of experience; so that structures which we now only know as occurring in association, may ultimately be found dissociated, and conjoined with other structures of a different character.

10. CLASSIFICATION.

Classification is the arrangement of a number of diverse objects into larger or smaller groups, according as they exhibit more or less likeness to one another. The excellence of any given classification will depend upon the nature of the points which are taken as determining the resemblance. Systems of classification, in which the groups are founded upon mere external and superficial points of similarity, though often useful in the earlier stages of science, are always found in the long-run to be inaccurate. It is needless, in fact, to point out that many living beings, the structure of which is fundamentally different, may nevertheless present such an amount of adaptive external resemblance to one another, that they would be grouped together in any "artificial" classification. Thus, to take a single example, the whale, by its external characters, would certainly be grouped amongst the fishes, though widely removed from them in all the essential points of its structure. "Natural" systems of classification, on the other hand, endeavour to arrange animals into divisions founded upon a due consideration of *all* the essential and fundamental points of structure, wholly irrespective of external similarity of form and habits. Philosophical classification depends upon a due appreciation of what constitute the true points of difference and likeness amongst animals; and we have already seen that these are morphological type and specialisation of function. Philosophical classification, therefore, is a formal expression of the facts and laws of Morphology and Physiology. It follows that the more fully the programme of a philosophical and strictly natural classification can be carried out, the more completely does it afford a condensed exposition of the fundamental construction of the objects classified. Thus, if the whale were placed by an artificial grouping amongst the fishes, this would simply express the facts that its habits are aquatic and its body fish-like. When, on the contrary, we obtain a natural classification, and we learn that the whale is placed amongst the Mammalia, we then know at once that the young whale is born in a comparatively helpless condition, and that its mother is provided with special mammary glands for its support; this expressing a fundamental distinction from all fishes, and being associated with other equally essential correlations of structure.

The entire animal kingdom is primarily divided into some half-a-dozen great plans of structure, the divisions thus formed being called "sub-kingdoms." The sub-kingdoms are, in turn, broken up into classes, classes into orders, orders into families, families into genera, and genera into species. We shall examine these successively, commencing with the consideration of a species, since this is the zoological unit of which the larger divisions are made up.

Species.—No term is more difficult to define than "species," and on no point are zoologists more divided than as to what should be understood by this word. Naturalists, in fact, are not yet agreed as to whether the term species expresses a real and permanent distinction, or whether it is to be regarded merely as a convenient, but not immutable, abstraction, the employment of which is necessitated by the requirements of classification.

By Buffon "species" is defined as "a constant succession of individuals * similar to and capable of reproducing each other."

De Candolle defines species as an assemblage of all those individuals which resemble each other more than they do others; and are able to reproduce their like, doing so by the generative process, and in such a manner that they may be supposed by analogy to have all descended from a single being or a single pair.

M. de Quatrefages defines species as "an assemblage of individuals, more or less resembling one another, which are descended, or may be regarded as being descended, from a single primitive pair by an uninterrupted succession of families."

Müller defines species as "a living form, represented by individual beings, which reappears in the product of generation with certain invariable characters, and is constantly reproduced by the generative act of similar individuals."

According to Pritchard, a species is constituted by "separate origin, and distinctness of race, evinced by a constant transmission of some characteristic peculiarity of organisation."

According to Woodward, "all the specimens, or individuals, which are so much alike that we may reasonably believe them to have descended from a common stock, constitute a *species.*"

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* In using the term "individual," it must be borne in mind that the "zoological individual" is meant; that is to say, the total result of the development of a single ovum, as will hereafter be explained at greater length.

From the above definitions it will be at once evident that there are two leading ideas in the minds of zoologists when they employ the term species; one of these being a certain amount of resemblance between individuals, and the other being the proof that the individuals so resembling each other have descended from a single pair, or from pairs exactly similar to one another. The characters in which individuals must resemble one another in order to entitle them to be grouped in a separate species, according to Agassiz, "are only those determining size, proportion, colour, habits, and relations to surrounding circumstances and external objects."

On a closer examination, however, it will be found that these two leading ideas in the definition of species—external resemblance and community of descent—are both defective, and liable to break down if rigidly applied. Thus, there are in nature no assemblages of plants or animals usually grouped together into a single species, the individuals of which *exactly* resemble one another in every point. Every naturalist is compelled to admit that the individuals which compose any so-called species, whether of plants or animals, differ from one another to a greater or less extent, and in respects which may be regarded as more or less important. The existence of such individual differences is attested by the universal employment of the terms "varieties" and "races." Thus a "variety" comprises all those individuals which possess some distinctive peculiarity in common, but do not differ in other respects from another set of individuals sufficiently to entitle them to take rank as a separate species. A "race," again, is simply a permanent or "perpetuated" variety. The question, however, is this—How far may these differences amongst individuals obtain without necessitating their being placed in a separate species? In other words: How great is the amount of individual difference which is to be considered as merely "*varietal*," and at what exact point do these differences become of "*specific*" value? To this question no answer can be given, since it depends entirely upon the weight which different naturalists would attach to any given individual difference.* Distinctions which appear to one observer as sufficiently great to entitle the individuals possessing them to be grouped as a distinct species, by another are looked upon as simply of varietal value; and, in the nature of the case, it seems impossible to lay down any definite rules. To such an extent do individual differences sometimes exist in particular genera—termed "protean" or "polymorphic" genera—that the determination of the different species and varieties becomes an almost hopeless task.

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* As an example of this, it is sufficient to allude to the fact that hardly any two botanists agree as to the number of species of Willows and Brambles in the British Isles. What one observer classes as mere varieties, another regards as good and distinct species.

Besides the individual differences which ordinarily occur in all species, other cases occur in which a species consists normally and regularly of two or even three distinct forms, which cannot be said to be mere varieties, since no intermediate forms can be discovered. When two such distinct forms exist, the species is said to be "dimorphic," and when three are present, it is called "trimorphic." Thus, in dimorphic plants a single species is composed of two distinct forms, similar to one another in all respects except in their reproductive organs, the one form having a long pistil and short stamens, the other a short pistil with long stamens. In trimorphic plants, the species is composed of three such distinct forms, which differ in like manner in the conformation of their reproductive organs, though they are otherwise undistinguishable (Darwin). Similar cases are known in animals, but in them the differences, though apparently connected with reproduction, are not confined to the reproductive organs. Thus the females of certain butterflies normally appear under two or three entirely different forms, not connected by any intermediate links; and the same thing occurs in some of the Crustacea.

As regards, therefore, the first point in the definition of species—namely, the external resemblance of assemblages of individuals—we are forced to conclude that no two individuals are exactly alike; and that the amount and kind of external resemblance which constitutes a species is not a precise and invariable quantity, but depends upon the value attached to particular characters by any given observer.

The second point in the definition of species—namely, community of descent—is hardly in a more satisfactory condition, since the descent of any given series of individuals from a single pair, or from pairs exactly similar to one another, is at best but a probability, and is in no case capable of proof. In the case of the higher animals, it can doubtless be shown that certain assemblages of individuals possess amongst themselves the power of fecundation and of producing fertile progeny, and that this power does not extend to the fecundation of individuals belonging to another different assemblage. Amongst the higher animals, "crosses" or "hybrids" can only be produced between closely-allied species, and when produced they are sterile, and are not capable of reproducing their like. In these cases, therefore, we may take this as a most satisfactory element in the definition of "species." The sterility, however, of hybrids is not universal, even amongst the higher animals; and amongst plants no doubt can be entertained but that the individuals of species universally admitted to be distinct are capable of mutual fertilisation; the hybrid progeny thus produced being likewise fertile, and capable of reproducing similar individuals. That this fertility is often irregular, and may be destroyed in a few generations, admits of explanation, and hardly alters the significance of these undoubted facts.

Upon the whole, then, it seems in the meanwhile safest to adopt a definition of species which implies no theory, and does not include the belief that the term necessarily expresses a fixed and permanent quantity. Species, therefore, may be defined as *an assemblage of individuals which resemble each other in their essential characters, are able, directly or indirectly, to produce fertile individuals, and which do not (as far as human observation goes) give rise to individuals which vary from the general type through more than certain definite limits.* The production of occasional monstrosities does not, of course, invalidate this definition.

Genus is a term applied to groups of species which possess a community of essential details of structure. A genus may include a single species only, in cases where the combination of characters which make up the species are so peculiar that no other species exhibits similar structural characters; or, on the other hand, it may contain many hundreds of species.

Families are groups of genera which agree in their general characters. According to Agassiz, they are divisions founded upon peculiarities of "form as determined by structure."

Orders are groups of families related to one another by structural characters common to all.

Classes are larger divisions, comprising animals which are formed upon the same fundamental plan of structure, but differ in the method in which the plan is executed (Agassiz).

Sub-kingdoms are the primary divisions of the animal kingdom, which include all those animals which are formed upon the same structural or morphological type, irrespective of the degree to which specialisation of function may be carried.

Impossibility of a Linear Classification.—It has sometimes been thought that the animal kingdom can be arranged in a linear series, every member of the series being higher in point of organisation than the one below it. As we have seen, however, the *status* of any given animal depends upon two conditions — one its morphological type, the other the degree to which specialisation of function is carried. Now, if we take two animals, one of which belongs to a lower morphological type than the other, no degree of specialisation of function, however great, will place the former above the latter, as far as its *type of structure* is concerned, though it may make the former a more highly organised animal. Every Vertebrate animal, for example, belongs to a higher morphological type than every Mollusc; but the higher Molluscs, such as cuttle-fishes, are much more highly organised, as far as their type is concerned, than are the lowest Vertebrata. In a linear classification, therefore, the cuttle-fishes should be placed above the lowest fishes—such as the lancelet—in spite of the fact that the type upon which the latter are constructed is by far the higher of the two.

It is obvious, therefore, that a linear classification is not possible, since the higher members of each sub-kingdom are more highly organised than the lower forms of the next sub-kingdom in the series, at the same time that they are constructed upon a lower morphological type.

In the words of Professor Allen Thomson, "It has become more and more apparent in the progress of morphological research, that the different groups form circles which touch one another at certain points of greatest resemblance, rather than one continuous line, or even a number of lines which partially pass each other." In the same way the highest vegetables do not approximate to, or graduate into, the lowest animals; but "each kingdom presents, as it were, a radiating expansion into groups for itself, so that the relations of the two kingdoms might be represented by the divergence of lines spreading in two different directions from a common point."

BINOMIAL NOMENCLATURE.—Since the time of Linnæus it has been the practice of naturalists to designate all *species* by double designations, the first part of the title indicating the *genus* to which the animal belongs, whilst the second is the proper or *specific* title. Thus the Dog is known by the "binomial" designation of *Canis familiaris*. The "*genus*" *Canis* contains other species besides the Dog—such as the Wolf and Jackal—but the name *familiaris* indicates that this title belongs to the Dog and not to either of the latter. The genus *Canis*, again, belongs to the "*family*" *Canidæ*, including other genera, such as the Foxes (*Vulpes*). The family *Canidæ*, further, is one of a number of families, such as the Cats (*Felidæ*), the Bears (*Ursidæ*), the Hyænas (*Hyænidæ*), &c., which collectively constitute the "*order*" of the *Carnivora* or Beasts of Prey. The *Carnivora*, again, constitute one of many orders of quadrupeds, which are distinguished by suckling their young and by other common characters, and which collectively constitute the "*class*" *Mammalia.* Finally, the *Mammalia* are united with the classes of the Birds, Reptiles, Amphibians, and Fishes to constitute the great primary division or "*sub-kingdom*" of *Vertebrata* or "Vertebrate animals;" since all these classes agree with one another in certain fundamental points of structure.

Condensing the above, the name of *Canis familiaris*, as applied to the Dog, *implies* a large amount of information as to the precise zoological position and affinities of the animal. Its title, namely, if expressed in full, would indicate its systematic place to be as follows:—

Sub-kingdom, VERTEBRATA.
  Class, *Mammalia.*
  Order, *Carnivora.*
  Family, *Canidæ.*
  Genus, *Canis.*
  Species, *Canis familiaris.*

11. REPRODUCTION.

Reproduction is the process whereby new individuals are generated and the perpetuation of the species insured. The methods in which this end may be attained exhibit a good deal of diversity, but they may be all considered under two heads.

I. *Sexual Reproduction.*—This consists essentially in the production of two distinct elements, a germ-cell or ovum, and a sperm-cell or spermatozoid, by the contact of which the ovum—now said to be "fecundated"—is enabled to develop itself into a new individual. As a rule, the germ-cell is produced by one individual (female) and the spermatic element by another (male); in which case the sexes are said to be distinct, and the species is said to be "diœcious." In other cases the same individual has the power of producing both the essential elements of reproduction; in which case the sexes are said to be united, and the individual is said to be "hermaphrodite," "androgynous," or "monœcious." In the case of hermaphrodite animals, however, self-fecundation—contrary to what might have been expected—rarely constitutes the reproductive process; and, as a rule, the reciprocal union of two such individuals is necessary for the production of young. Even amongst hermaphrodite plants, where self-fecundation may, and certainly does, occur, provisions seem to exist by which perpetual self-fertilisation is prevented, and the influence of another individual secured at intervals.* Amongst the higher animals sexual reproduction is the only process whereby new individuals can be generated.

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* It seems to have been established as a strong probability by Darwin, Hildebrandt, and Delpino, that in the great majority of plants self-fecunda-

II. *Non-sexual Reproduction.*—Amongst the lower animals fresh beings may be produced without the contact of an ovum and a spermatozoid; that is to say, without any true generative act. The processes by which this is effected vary in different animals, and are all spoken of as forms of "asexual" or "agamic" reproduction ("agamogenesis"). As we shall see, however, the true "individual" is very rarely produced otherwise than sexually, and most forms of agamic reproduction are really modifications of growth.

a. Gemmation and Fission.—Gemmation, or budding, consists in the production of a bud, or buds, generally from the exterior, but sometimes from the interior, of the body of an animal, which buds are developed into independent beings, which may or may not remain permanently attached to the parent organism. Fission differs from gemmation solely in the fact that the new structures in the former case are produced by a division of the body of the original organism into separate parts, which may remain in connection, or may undergo detachment.

The simplest form of gemmation, perhaps, is seen in the power possessed by certain animals of reproducing parts of their bodies which they may have lost. Thus, the Crustacea possess the power of reproducing a lost limb, by means of a bud which is gradually developed till it assumes the form and takes the place of the missing member. In these cases, however, the process is not in any way generative, and the product of gemmation can in no sense be spoken of as a distinct being (or zoöid).

An excellent example, however, of true gemmation is exhibited in such an organism as the common sea-mat (Flustra), which is a composite organism composed of a multitude of similar beings, each of which inhabits a little chamber, or cell; the whole forming a structure not unlike a sea-weed in appearance. This colony is produced by gemmation from a single primitive being ("polypide"), which throws out buds, each of which repeats the process, apparently almost indefinitely. All the buds remain in contact and connected with one another, but each is, nevertheless, a distinct and independent being,

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tion never occurs, but the plant is fertilised by the intervention of insects. Thus, in many plants the stamens and pistil arrive at maturity at different times, whilst in others the stamens and stigma are placed at different heights in the flower, and do not always occupy the same position even in a single species.

capable of performing all the functions of life. In this case, therefore, each one of the innumerable buds becomes an independent being, similar to, though not detached from, the organism which gave it birth. This is an instance of what is called "continuous gemmation."

In other cases—as in the common fresh-water polype or Hydra—the buds which are thrown out by the primitive organism become developed into creatures exactly resembling the parent, but, instead of remaining permanently attached, and thus giving rise to a compound organism, they are detached to lead an entirely independent existence. This is a simple instance of what is termed "discontinuous gemmation."

The method and results of fission may be regarded as essentially the same as in the case of gemmation. The products of the division of the body of the primitive organism may either remain undetached, when they will give rise to a composite structure (as in many corals), or they may be thrown off and live an independent existence (as in some of the Hydrozoa).

We are now in a position to understand what is meant, strictly speaking, by the term "individual." In zoological language, an *individual* is defined as "*equal to the total result of the development of a single ovum.*" Amongst the higher animals there is no difficulty about this, for each ovum gives rise to no more than one single being, which is incapable of repeating itself in any other way than by the production of another ovum; so that an individual is a single animal. It is most important, however, to comprehend that this is not necessarily or always the case. In such an organism as the sea-mat, the ovum gives rise to a primitive polypide, which repeats itself by a process of continuous gemmation until an entire colony is produced, each member of which is independent of its fellows, and is capable of producing ova. In such a case, therefore, the term "individual" must be applied to the entire colony, since this is the result of the development of a single ovum. The separate beings which compose the colony are technically called zoöids. In like manner the Hydra, which produces fresh and independent Hydræ by discontinuous gemmation, is not an "individual," but a zoöid. Here the zoöids are not permanently united to one another, and the "individual" Hydra consists really of the primitive Hydra, *plus* all the detached Hydræ to which it gave rise. In this case, therefore, the "individual" is composed of a number of disconnected and wholly independent beings, all of which are the result of the development of a single ovum. It is to be remembered that both the parent zoöid and the "produced zoöids" are capable of giving rise to fresh Hydræ by a true generative process. It must also be borne in mind that this production of fresh zoöids by a process of gemmation is not so essentially different from the true sexual process of reproduction as might at first sight appear, since the ovum itself may be regarded merely as a highly specialised bud. In the Hydra, in fact, where the ovum is produced as an external process of the wall of the body, this likeness is extremely striking. The ovarian bud, however, differs from the true gemmæ or buds in its inability to develop itself into an independent organism, unless previously brought into contact with another special generative element. The only exceptions to this statement are in the rare cases of true "parthenogenesis," to be subsequently alluded to.

b. Reproduction by Internal Gemmation.—Before considering the phenomena of "alternate generations," it will be as well to glance for a moment at a peculiar form of gemmation exhibited by some of the Polyzoa, which is in some respects intermediate between ordinary discontinuous gemmation and alternation of generations. These organisms are nearly allied to the sea-mat already spoken of, and, like it, can reproduce themselves by continuous gemmation (forming colonies), by a true sexual process, and rarely by fission. In addition to all these methods they can reproduce themselves by the formation of peculiar internal buds, which are called "statoblasts." These buds are developed upon a peculiar cord, which crosses the body-cavity, and is attached at one end to the fundus of the stomach. When mature they drop off from this cord, and lie loose in the cavity of the body, whence they are liberated on the death of the parent organism. When thus liberated, the statoblast, after a longer or shorter period, ruptures and gives exit to a young Polyzoön, which has essentially the same structure as the adult. It is, however, simple, and has to undergo a process of continuous gemmation before it can assume the compound form proper to the adult.

As regards the nature of these singular bodies, "the invariable absence of germinal vesicle and germinal spot, and their never exhibiting the phenomena of yelk-cleavage, independently of the conclusive fact that true ova and ovary occur elsewhere in the same individual, are quite decisive against their being eggs. We must then look upon them as *gemmæ* peculiarly encysted, and destined to remain for a period in a quiescent or pupa-like state" (Allman).

c. Alternation of Generations.—In the case of the Hydra and the sea-mat, which we have considered above, fresh zoöids are produced by a primordial organism by gemmation; the beings thus produced (as well as the parent) being capable not only of repeating the gemmiparous process, but also of producing new individuals by a true generative act. We have now to consider a much more complex series of phenomena, in which the organism which is developed from the primitive ovum produces by gemmation *two* sets of zoöids, one of which is destitute of sexual organs, and is capable of performing no other function than that of nutrition, whilst the other is provided with reproductive organs, and is destined for the perpetuation of the species. In the former case the produced zoöids all resembled each other, and the parent organism which gave rise to them; in the latter case, the produced zoöids are often utterly unlike each other and unlike the parent, since their functions are entirely different.

The simplest form of the process is seen in certain of the Hydroid Polypes, such as Hydractinia. The embryo of Hydractinia is a free-swimming ciliated body, which, after a short locomotive existence, attaches itself to some submarine object, develops a mouth and tentacles, and commences to produce zoöids like itself by a process of continuous gemmation. These remain permanently attached to one another, with the result that a compound organism is produced, consisting of a number of zoöids, or "polypites," organically connected together, but enjoying an independent existence. None of the zoöids, however, are provided with sexual organs; and though there is theoretically no limit to the size which the colony may reach by gemmation, its buds are not detached, and the species would therefore die out, unless some special provision were made for its preservation. Besides these nutritive zoöids, however, other buds are produced which differ considerably in appearance from the former, and which have the power of generating the essential elements of reproduction. These generative zoöids derive their nourishment from the materials collected by the nutritive zoöids, but only live until the ova are matured in their interior and liberated, when they disappear. The ova thus produced become free-swimming ciliated bodies, such as the one with which the cycle began.

In this case, therefore, the "individual" consists of a series of nutritive zoöids, collectively called the "trophosome," and another series of reproductive zoöids, collectively called the "gonosome," the entire series remaining in organic connection.

In other Hydroid Zoophytes allied to the preceding (such as *Clytia*), the process advances a step further. In *Clytia*, the generative buds or zoöids do not produce the reproductive elements as long as they remain attached to the parent colony; but they require a preliminary period of independent existence. For this purpose they are specially organised, and when sufficiently mature they are detached from the stationary colony. The generative zoöid now appears as an entirely independent being, described as a species of jelly-fish (or Medusa). It consists of a bell-shaped disc, by means of which it is enabled to swim freely; from the centre of this disc depends a nutritive process, with a mouth and digestive cavity, whereby the organism is able to increase considerably in size. The substance of the disc is penetrated by a complex system of canals, and from its margin hangs a series of tentacular processes. After a period of independent locomotive existence, the Medusa attains its full growth, when it develops ova and spermatozoa. By the contact of these, embryos are produced; but these, instead of resembling the jelly-fish by which they were immediately generated, proceed to develop themselves into the fixed Hydroid colony by which the Medusa was originally produced.

Still more extraordinary phenomena have been discovered in other Hydrozoa, as in many of the Lucernarida. In these the ovum gives rise to a locomotive ciliated body, which ultimately fixes itself, becomes trumpet-shaped, and develops a mouth and tentacles at its expanded extremity, when it is known as the "hydra-tuba," from its resemblance to the fresh-water polype, or Hydra. The hydra-tuba has the power of multiplying itself by gemmation, and it can produce large colonies in this way; but it does not obtain the power of generating the essential elements of reproduction. Under certain circumstances, however, the hydra-tuba enlarges, and, after a series of preliminary changes, divides by tranverse fission into a number of segments, each of which becomes detached and swims away. These liberated segments of the little hydra-tuba (it is about half an inch in height) now live as entirely independent beings, which were described by naturalists as distinct animals, and were called Ephyræ. They are provided with a swiming-bell, or "umbrella," by means of which they propel themselves through the water, and with a mouth and digestive cavity. They now lead an active life, feeding eagerly, and attaining in some instances a perfectly astonishing size (the Medusoids of some species are several feet in circumference). After a while they develop the essential elements of reproduction, and after the fecundation and liberation of their ova they die. The ova, however, are not developed into the free-swimming and comparatively gigantic jelly-fish by which they were immediately produced, but into the minute, fixed, sexless hydra-tuba.

We thus see that a small sexless zoöid, which is capable of multiplying itself by gemmation, produces by fission several independent locomotive beings, which are capable of nourishing themselves and of performing all the functions of life. In these are produced generative elements, which give rise by their development to the little fixed creature with which the series began.

To the group of phenomena of which the above are examples, the name "alternation of generations" was applied by Steenstrup; but the name is not an appropriate one, since the process is truly an alternation of generation with gemmation or fission. The only generative act takes place in the reproductive zoöid, and the production of this from the nutritive zoöid is a process of gemmation or fission, and not a process of generation. The "individual," in fact, in all these cases must be looked upon as a double being composed of two factors, both of which lead more or less completely independent lives, the one being devoted to nutrition, the other to reproduction. The generative being, however, is in many cases not at first able to mature the sexual elements, and is therefore provided with the means necessary for its growth and nourishment as an independent organism. It must also be remembered that the nutritive half of the "individual" is usually, and the generative half sometimes, *compound*—that is to say, composed of a number of zoöids produced by continuous gemmation; so that the zoological individual in these cases becomes an extremely complex being.

These phenomena of so-called "alternation of generations," or "metagenesis," occur in their most striking form amongst the Hydrozoa; but they occur also amongst many of the intestinal worms (Entozoa), and amongst some of the Tunicata (Molluscoida).

d. Parthenogenesis.—"Parthenogenesis" is the term employed to designate certain singular phenomena, resulting in the production of new individuals by virgin females without the intervention of a male. By Professor Owen, who first employed the term, parthenogenesis is applied also to the processes of gemmation and fission, as exhibited in sexless beings or in virgin females; but it seems best to consider these phenomena separately. Strictly the term parthenogenesis ought to be confined to the production of new individuals from virgin females by means of *ova*, which are enabled to develop themselves without the contact of the male element. The difficulty in this definition is found in framing an exact definition of an ovum, such as will distinguish it from an internal gemma or bud. No body, however, should be called an "ovum" which does not exhibit a germinal vesicle and germinal spot, and which does not exhibit the phenomenon known as segmentation of the yelk. Moreover, ova are almost invariably produced by a special organ, or ovary.

As examples of parthenogenesis, we may take the cases of the Plant-lice (Aphides), the Honey-bee, and certain Crustacea; though in the case of the first of these it is possible that the phenomena observed may admit of explanation otherwise than as an instance of parthenogenesis strictly so called.

The Aphides, or plant-lice, which are so commonly found parasitic upon plants, are seen towards the close of autumn to consist of male and female individuals. By the sexual union of these true ova are produced, which remain dormant through the winter. At the approach of spring these ova are hatched; but instead of giving birth to a number of males and females, all the young are of one kind, variously regarded as neuters, virgin females, or hermaphrodites. Whatever their true nature may be, these individuals produce, *viviparously*, a brood of young which resemble themselves; and this second generation, in like manner, produces a third,—and so the process may be repeated, for as many as ten or more generations, throughout the summer. When the autumn comes on, however, the viviparous Aphides produce—in exactly the same manner—a final brood, but this, instead of being composed entirely of similar individuals, is made up of males and females. Sexual union now takes place, and ova are produced and fecundated in the ordinary manner.

The viviparous Aphides are either wingless or winged; and the number of young produced is so great, that it has been calculated that a single Aphis might in this way be, during the summer months, and by the time the tenth generation was reached, the progenitor of no less than one quintillion of individuals. Each viviparous Aphis possesses an ovary, which only differs from that of the fertile females in being without certain secondary adjuncts (the colleterial gland and spermatheca). This "pseudovarium" produces egg-like bodies or "pseudova," which are directly developed into young Aphides —the latter being thus produced by "the individualisation of previously organised tissue."

The differences between the "pseudova" and true ova are in no way anatomical, but are wholly physiological; and the decision involved in the viviparous reproduction of the Aphides turns simply upon the question as to whether the viviparous individuals possess, in addition to the pseudovarium, a testis, or whether male organs are absent. Most observers maintain that the viviparous Aphides are wholly destitute of male organs of reproduction, in which case the phenomena just described can only be explained as an example of parthenogenesis. On the other hand, Balbiani maintains that the viviparous Aphides are really hermaphrodite, in which case, of course, the phenomena are of a much less abnormal character.

In the second case of alleged parthenogenesis which we are about to examine—namely, in the honey-bee—the phenomena which have been described are now generally accepted as free from doubt. A hive of bees consists of three classes of individuals: 1, a "queen," or fertile female; 2, the "workers," which form the bulk of the community, and are really undeveloped or sterile females; and, 3, the "drones," or males, which are only produced at certain times of the year. We have here three distinct sets of beings, all of which proceed from a single fertile individual; and the question arises, In what manner are the differences between these produced? At a certain period of the year the queen leaves the hive, accompanied by the drones (or males), and takes what is known as her "nuptial flight" through the air. In this flight she is impregnated by the males; and in virtue of this single impregnation, she is enabled to produce fresh individuals for a lengthened period, the semen of the males being stored up in a receptacle which communicates by a tube with the oviduct, from which it can be shut off at will. The ova which are to produce workers (undeveloped females) and queens (fertile females) are fertilised on their passage through the oviduct, the semen being allowed to escape into the oviduct for this purpose. The subsequent development of these fecundated ova into workers or queens depends entirely upon the form of the cell into which the ovum is placed, and upon the nature of the food which is supplied to the larva. So far there is no doubt as to the nature of the phenomena which are observed. It is asserted, however, by Dzierzon and Siebold, that the males or drones are produced by the queen from ova which she does not allow to come into contact with the semen as they pass throught the oviduct. This assertion is supported by the fact that if the communication between the receptacle for the semen and the oviduct be cut off, the queen will produce nothing but males. Also, in crosses between the common honey-bee and the Ligurian bee, the queens and workers alone exhibit any intermediate characters between the two forms, the drones presenting the unmixed characters of the queen by whom they were produced.

If these observations are to be accepted as established—and there can be no hesitation in accepting them as in the main correct—then the drones are produced by a true process of parthenogenesis; but some observers maintain that the development of any given ovum into a drone is really due—as in the case of the queens and workers—to the special circumstances under which the larva is brought up.*

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* In the case of *Polistes Gallica*, Von Siebold appears to have proved

Among the Crustaceans, parthenogenesis has been established as occurring in some of the water-fleas (*Cladocera*) and in various of the Phyllopods (*Apus*, *Limnadia*, *Artemia*, &c.) In these latter it is the female which is produced parthenogenetically; whereas in the honey-bee and in *Polistes* it is the male.

There are various other cases in which parthenogenesis is said to occur, but the above will suffice to indicate the general character of the phenomena in question. The *theories* of parthenogenesis appear to be too complex to be introduced here; and there is the less to regret in their omission, as naturalists have not yet definitely adopted any one explanation of the phenomena to the exclusion of the rest.

From the phenomena of asexual reproduction in all its forms, M. de Quatrefages has deduced the following generalisation:—

"The formation of new individuals may take place, in some instances, by gemmation from, or division of, the parent-being; but this process is an exhaustive one, and cannot be carried out indefinitely. When, therefore, it is necessary to insure the continuance of the species, the sexes must present themselves, and the germ and sperm must be allowed to come in contact with one another."

It should be added that the act of sexual reproduction, though it insures the perpetuation of the *species*, is very destructive to the life of the *individual*. The formation of the essential elements of reproduction appears to be one of the highest physiological acts of which the organism is capable, and it is attended with a corresponding strain upon the vital energies. In no case is this more strikingly exhibited than in the case of insects, many of which pass the greater portion of their existence in a sexually immature condition, and die almost immediately after they have become sexually perfect and have consummated the act whereby the perpetuation of the species is secured.

12. DEVELOPMENT, TRANSFORMATION, AND METAMORPHOSIS.

Development is the general term applied to all those changes which a germ undergoes before it assumes the characters of

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beyond reasonable doubt that the males are produced by a process of parthenogenesis. Landois, however, asserts that the eggs of insects are of no sex, that sex is only developed in the larva after its emergence from the egg, and that in each individual larva the sex is determined wholly by the nature of the food upon which it is brought up; abundant nourishment producing females, and scanty diet giving rise to males.

the perfect individual; and the chief differences which are observed in the process as it occurs in different animals consist simply in the extent to which these changes are external and visible, or are more or less completely concealed from view. For these differences the terms "transformation" and "metamorphosis" are employed; but they must be regarded as essentially nothing more than variations of development.

Transformation is the term employed by Quatrefages to designate "the series of changes which every germ undergoes in reaching the embryonic condition; those which we observe in every creature still within the egg; those, finally, which the species born in an imperfectly developed state present in the course of their external life."

Metamorphosis is defined by the same author as including the alterations which are "undergone after exclusion from the egg, and which alter extensively the general form and mode of life of the individual."

Though by no means faultless, these terms are sufficiently convenient, if it be remembered that they are merely modifications of development, and express differences of degree and not of kind. An insect, such as a butterfly, is the best illustration of what is meant by these terms. All the changes which are undergone by a butterfly in passing from the fecundated ovum to the condition of an imago, or perfect insect, constitute its *development*. The egg which is laid by a butterfly undergoes a series of changes which eventuate in its giving birth to a caterpillar, these preliminary changes constituting its *transformation*. The caterpillar grows rapidly, and after several changes of skin becomes quiescent, when it is known as a "chrysalis." It remains for a longer or shorter time in this quiescent and apparently dead condition, during which period developmental changes are going on rapidly in its interior. Finally, the chrysalis ruptures, and there escapes from it the perfect winged insect. To these changes the term *metamorphosis* is rightly applied. These changes, however, do not differ in kind from the changes undergone by a Mammal; the difference being that in the case of a Mammal the ovum is retained within the body of the parent, where it undergoes the necessary developmental changes, so that at birth it has little to do but grow, in order to be converted into the adult animal.

From these considerations we arrive at a second generalisation, which is thus formulated by Quatrefages: "Those creatures whose ova—owing to an insufficient supply of nutritious contents, and an incapacity on the part of the mother to provide for their complete development within her own substance—are rapidly hatched, give birth to imperfect offspring, which, in proceeding to their definitive characters, undergo several alterations in structure and form, known as metamorphoses."

Retrograde Development.—Ordinarily speaking, the course of development is an ascending one, and the adult is more highly organised than the young; but there are cases in which there is an apparent reversal of this law, and the adult is to all appearance a degraded form when compared with the embryo. This phenomenon is known as "retrograde" or "recurrent" development; and well-marked instances are found amongst the Cirripedia and Lernææ, both of which belong to the Crustacea.

Thus, in the Cirripedes (acorn-shells, &c.) and in the parasitic Lernææ (fig. 3), the embryo is free-swimming and provided with organs of vision and sensation, being in many respects similar to the permanent condition of certain other Crustacea, such as the Copepods. The adult, however, in both cases, is degraded into a more or less completely sedentary animal, more or less entirely deprived of organs of sense, and leading an almost vegetative life. As a compensation, reproductive organs are developed in the adult, and it is in this respect superior to the locomotive, but sexless, larva.

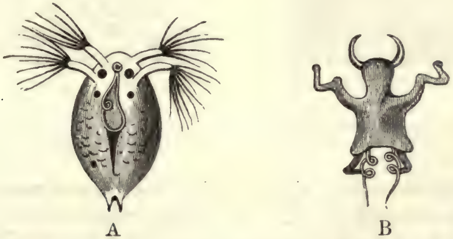


Fig. 3.—A, Young of one of the parasitic Crustaceans (*Achtheres*) with its swimming-paddles and eye-spots, magnified; B, Deformed and swollen parasitic adult of another member of the same group (*Lernæa*).

13. SPONTANEOUS GENERATION.

Spontaneous or Equivocal generation is the term applied to the alleged production of living beings without the pre-existence of germs of any kind, and therefore without the pre-existence of parent organisms. The question is one which has been long and closely disputed, and is far from being settled; so that it will be sufficient to indicate the facts upon which the theory rests.

If an animal or vegetable substance be soaked in hot or cold water, so as to make an organic infusion, and if this infusion be exposed for a sufficient length of time to the air, the following series of changes is usually observed:—

1. At the end of a longer or shorter time, there forms upon the surface of the infusion a thin scum, or pellicle, which, when examined microscopically, is found to consist of an incalculable number of extremely minute molecules (fig. 4, A).

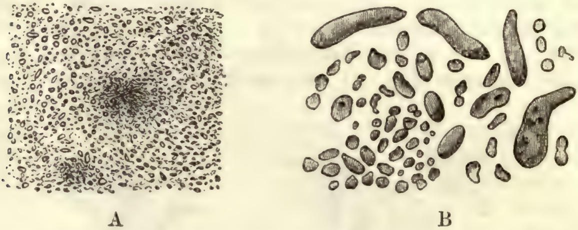


Fig. 4.—A, Living particles or molecules developed in organic infusions; B, Bacteria developed in organic infusions, highly magnified. (After Beale.)

2. In the next stage these molecules appear, many of them, to have increased in size by endogenous division, till they form short staff-shaped filaments, called "bacteria" (fig. 4, B). Others increase in length by the same process until we get long filamentous bodies produced, which are termed "vibriones." Both the bacteria and the vibrios now exhibit a vibratile or serpentine movement through the surrounding fluid.

3. After a varying period, the bacteria and vibrios become motionless, and disintegrate so as to produce again a finely molecular pellicle.

4. Little spherical bodies may now appear, each of which is provided with a vibratile cilium with which it moves actively through the infusion (Monas lens).

5. Varied forms of ciliated Infusoria—some of which possess a mouth and are otherwise highly organised—may make their appearance in the fluid.

The above is the general sequence of the phenomena which have been observed, and the following are the two theories which have been advanced to account for them:—

a. By the advocates of spontaneous generation, "Abiogenesis" or "Heterogeny," it is affirmed that the Infusoria which finally appear in the infusion are produced spontaneously out of the molecular pellicle, the molecules of which are also of spontaneous origin, and are not derived from any preexisting germs.

b. By the "panspermists," or the opponents of spontaneous generation, it is alleged, on the other hand, that the production of Bacteria, Vibrios, Monads, and Infusoria, in organic infusions, is due simply to the fact that the atmosphere, and probably the fluid itself, is charged with innumerable germs—too minute, perhaps, to be always detectable by the microscope—which, obtaining access to the fluid, and finding there favourable conditions, are developed into living beings.

A large number of elaborate experiments have been carried out to prove that atmospheric air is absolutely necessary for the production of these living beings, and that if the air be properly purified by passage through destructive chemical reagents, no such organisms will be produced, provided that the infusion have been previously boiled. As the results of all these experimental trials have hitherto proved more or less contradictory, it is unnecessary to enter into the question further, and it will be sufficient to indicate the following general considerations:—

a. The primary molecules which appear in the fluid are extremely minute, and if they are developed from germs, these may be so small as to elude any power of the microscope yet known to us. As they subsequently become converted into bacteria and vibrios, and as there can be little dispute as to these being truly living organisms, we are obliged to believe that they must have had *some* definite origin. It appears, however, to be hardly philosophical to assume that they form themselves out of the inorganic materials of the infusion; since this implies the sudden appearance, or creation, of new force, for which there seems to be no means of accounting.

b. The nature of the vibrios must be looked upon as uncertain. To say the least of it, they are quite as likely to be plants as animals; and the most probable hypothesis would place them near the filamentous Confervæ, or would regard them as the mycelium of various species of Moulds (*Penicillium*). The bacteria are undoubtedly of a vegetable nature, and referable to the *Algæ*.

c. What has been said above with regard to the origin of the bacteria and vibrios applies equally to the origin of the Monads, which appear in the infusion subsequently to the death of the vibrios.

d. These monads, as shown by recent researches, are probably to be looked upon as, in some cases at any rate, the embryonic, or larval, forms of the higher Infusoria which succeed them.

e. Many of the Infusoria which finally appear are of a comparatively high grade of organisation, being certainly the highest of the Protozoa, and being placed by some competent observers in the neighbourhood of the Trematode Worms (Scolecida). It is therefore very unlikely that these should be generated spontaneously; since, if this ever occurs, it is reasonable to suppose that the creatures thus produced will be of the lowest possible organisation (such as the Gregarinidæ or the Monera, for example), and will be far below the Infusoria in point of structure.

f. The reproductive process in many of these same Infusoria is perfectly well known, and it consists either in a true sexual process, for which proper organs are provided (as in Paramœcium), or in a process of gemmation or fission. It is therefore improbable that they should be generated in the manner maintained by the heterogenists, since this mode of reproduction would appear to be superfluous.

g. In the absence of any direct proof to the contrary, it is safer to adopt an explanation of the observed phenomena which does not have recourse to laws with which we are as yet unacquainted. Thus, it is not at variance with any known law to suppose that the primary molecules are the result of the development of germs which find in the organic infusion a suitable *nidus;* that these primary molecules and the vibrios which they produce are referable to the Protophyta, and should probably be placed near the filamentous Confervæ; that by the death of these vegetable organisms the fluid is prepared for the reception and development of the germs of the Protozoa, for which the former serve as *pabulum;* and that many of the forms which are observed are the larval stages of the higher Infusoria.

h. Recent researches, especially those of Dr Bastian, have established some new facts as to the possibility of spontaneous generation, but they can by no means be said to have settled the question, if only upon the ground that they require confirmation by other experimentalists. The chief fact which appears to have been established upon a tolerably firm basis is, that living beings, vegetable or animal, may make their appearance in organic infusions which have been subjected to a temperature of considerably over the boiling-point, even though the said infusions have been hermetically sealed in a flask from which all atmospheric air has been previously withdrawn. The chief deduction which appears to flow from this—assuming its correctness—is, that there are low organisms which can exist, for a certain length of time at any rate, with an extremely small amount of air; for it is to be remembered that the production of a theoretically perfect vacuum is probably practically impossible. If it were conceded, in fact, that a perfect vacuum *had* been formed in the experiments in question, the sole result would be that we should have to alter all our beliefs as to the conditions under which life is a possibility. The only tangible result of these experiments, so far, is, that any supposed "pre-existent germs" must have been contained, if present at all, in the infinitesimal portion of air which could not be expelled from the flasks experimented on; or, they must have been able to withstand without injury a temperature of over 212°. Mr Crace-Calvert, indeed, asserts that he has experimentally shown that vibrios can survive exposure to a temperature exceeding 300° Fahrenheit, and Messrs Dallinger and Drysdale have shown the same of the germs of bacteria. Neither of these hypotheses is wholly incredible; but the question ought to be regarded as still *sub judice*. Under any circumstances, the entire question is one of such complexity as to be altogether unsuited for discussion here.

i. Still more recent researches, carried out in a series of elaborate experiments by Professor Tyndall, have supplied us with a complete physical demonstration that ordinary atmospheric air is invariably charged with innumerable particles of solid matter, many of which are so immeasurably minute as to be incapable of detection by the highest known powers of the microscope. The same observer has further shown that vibrios and bacteria are never produced in organic infusions, which, subsequent to boiling, are exposed only to air from which these floating molecules have been completely removed. In the face of these observations, it is difficult to see how the doctrine of "abiogenesis" can maintain its ground.

14. ORIGIN OF SPECIES.

It is impossible here to do more than merely indicate in the briefest manner the two fundamental ideas which are at the bottom of all the various theories as to the origin of species; and it will be sufficient to give an outline of the two leading theories, without adducing any of the reasoning upon which they are based. It should be added, however, that almost all scientific men are at the present day agreed that species have been produced by a process of evolution or development, though all are not agreed as to the manner in which that evolution has been carried out.

I. *Doctrine of Special Creation.*—On this doctrine of the origin of species it is believed that species are immutable productions, each of which has been specially created at some point within the area in which we now find it, to meet the external conditions there prevailing, subsequently spreading from this spot as far as the conditions of life were suitable for it.

II. *Doctrine of Development.*—On the other hand, it is believed that species are not permanent and immutable, but that they "undergo modification, and that the existing forms of life are the descendants by true generation of pre-existing forms" (Darwin).

On Lamarck's theory of the development of species, the means of modification were ascribed to the action of external physical agencies, the inter-breeding of already existing forms, and the effects of habit.

The doctrine of the development of species by variation and natural selection — propounded by Darwin, and commonly known as the Darwinian theory—is based upon the following fundamental propositions:—

1. The progeny of all species of animals and plants exhibit variations amongst themselves in all parts of their organisation, no two individuals being exactly and in all respects alike. In other words, in every species the individuals, whilst inheriting a general likeness to their progenitors, tend by variation to diverge from the parent-type in some particular or other.

2. Variations arising in any part of the organism, however minute, may be transmitted to future generations, under certain definite and discoverable laws of inheritance.

3. By "artificial selection," or by breeding from individuals possessing any particular variation, man, in successive generations, can produce a breed in which the variation will be permanent, the divergence from the parent-type being usually intensified by the process of inter-breeding. The races thus artificially produced by men are often as widely different as are distinct species of wild animals.

4. The world in which all living beings are placed is one not absolutely unchanging, but is liable, on the contrary, to subject them to very varying conditions.

5. All animals and plants give rise to more numerous young than can by any possibility be preserved, each species tending to increase in numbers in a geometrical progression.

6. As these young are none of them exactly alike in all

respects, a process of "natural selection" will ensue, whereby those individuals which possess any variation, however slight, favourable to the peculiarities of the life of the species, will tend to be preserved. Those individuals, on the other hand, which do not possess any such favourable variation, will be placed at a disadvantage in the "struggle for existence," and will tend to be gradually exterminated. The individuals, therefore, composing any species are thus subjected to a rigid process of sifting, by which those least adapted to their environment are being perpetually weeded out, whilst "the survival of the fittest" is secured.

7. Other conditions remaining the same, the individuals which survive in the struggle for existence will transmit the variations to which they owe their preservation, to future generations.

8. By a repetition of this process, "varieties" are first established; these become permanent, and "races" are produced; finally, in the lapse of time, the differences thus caused become sufficiently marked to constitute distinct "species."

9. If we grant that past time has been practically infinite, it is conceivable that all the different animals and plants which we see at present upon the globe, may have been produced by the action of natural selection upon the offspring of a few primordial forms, or, it may be, of a single primitive being.

Originally, Mr Darwin appears to have believed that "natural selection" would alone be found to be a sufficient cause to have given rise to all existing species by a process of evolution from pre-existing forms. In view, however, of certain objections which had been brought forward, Mr Darwin seems to have abandoned this position; and a cause supplementary to "natural selection" was sought for in what Mr Darwin terms "sexual selection." The action of sexual selection in a supposed process of evolution, according to Mr Darwin's views, may be stated in the following two propositions:—

a. The males of many species of animals are known to engage in very severe contests for the possession of the females, these latter yielding themselves to the victor. In such contests certain males will inevitably have certain advantages over the others, either in point of strength or activity, or in consequence of the possession of more efficient offensive weapons. There will therefore always be a probability that certain males will get possession of the females in preference to others: and thus there will be a tendency in the individuals of many species of animals to secure a preponderance of offspring from the strongest males. The peculiarities which enable certain males to succeed in these contests will, *cæteris paribus*, be transmitted to their male offspring, and in this way variations may be perpetuated, initiated, or intensified.

b. In the preceding cases, the females are believed to be perfectly passive, and the selection is a "natural" one, the final result depending solely upon the natural advantages which certain males possess over others in actual combat. It is alleged, however, that there are other cases in which the selection is truly "sexual," since its result is determined by spontaneous preference, and not by brute force alone. It is asserted, namely, that among certain species of animals, the females exercise a free choice as to the particular male with which they will pair; the males being passive agents in the matter, except in so far as each uses, or may use, his utmost exertions to secure that the choice of the female may fall upon him. The circumstances supposed to influence, and ultimately determine, the choice of the female, are of course, in the main, the personal attractions of some particular male, the female being captivated by some "beauty of form, colour, odour, or voice," which such a male may possess.

If it be admitted that the females of some of the lower animals have the power of expressing and exercising a preference in the manner above indicated, then it is easy to understand how variations might be transmitted or intensified in this way. The male who is most attractive to the female will, other things being equal, have the best chance of propagating his species, and is likely to leave the largest number of descendants. His male offspring will inherit the peculiarities by which their sire was rendered pre-eminently attractive in the eyes of their mother, and thus a well-marked breed might be produced, by the preservation or intensification of characters of this nature. Mr Darwin is disposed to believe that colour and song in most, if not in all animals, are thus to be ascribed to the action of sexual selection, through numerous successive generations; but other competent authorities are unable to concur in this view.

15. DISTRIBUTION.

Under this head come all the facts which are concerned with the external or objective relations of animals—that is to say, their relations to the external conditions in which they are placed.

The *geographical* distribution of animals is concerned with the determination of the areas within which every species of animal is at the present day confined. Some species are found almost everywhere, when they are said to be "cosmopolitan;" but, as a rule, each species is confined to a limited and definite area. Not only are species limited in their distribution, but it is possible to divide the globe into a certain number of geographical regions or "zoological provinces," each of which is characterised by the occurrence in it of certain associated forms of animal life.

The geographical distribution of land animals is conditioned partly by the existence of suitable surroundings, and partly by the presence of barriers preventing migrations. Thus, certain contiguous regions might be equally suitable for the existence of the same animals, but they might belong to different zoological provinces, if separated by any impassable barrier, such as a lofty chain of mountains. Owing to their power of flight, the geographical distribution of birds is much less limited than that of mammals; and many migratory birds may be said to belong to two zoological provinces. In spite of their powers of locomotion, however, birds are limited by the necessities of their life to definite areas, and a zoological province may be marked by its birds just as well as by its quadrupeds.

The geographical distribution of an animal at the present day by no means necessarily coincides with its former extension in space. Many species are known which now occupy a much more restricted area than they did formerly, owing to changes in climate, the agency of man, or other causes. Similarly, there are species whose present area is much wider than it was originally.

At the present day, naturalists usually adopt either the zoological provinces proposed by Prof. Huxley, or those proposed by Mr Sclater, both arrangements possessing certain features in common. Prof. Huxley proposes to divide the earth's surface into four primary zoological provinces, as follows, each possessing its own "fauna," or characteristic assemblage of animals:—

I. *Ornithogæa*, or the *Novo-Zelanian Province*, comprising only New Zealand.

II. *Antarctogæa*, or the *Australian Province*, comprising Australia, Tasmania, and the Negrito Islands.

III. *Dendrogæa*, or the *Austro-Columbian Province*, including South America, Central America, and Mexico.

IV. *Arctogæa*, including all the rest of the world, and having as sub-provinces,—

1. North America, north of Mexico.
2. Africa, south of the Sahara.
3. Hindostan.
4. The remainder of the Old World (Europe, Africa north of the Sahara, Asia generally, but without Hindostan, &c.)

Mr Sclater, basing his arrangement primarily on the distribution of birds, divides the earth's surface into the following six provinces:—

1. The *Palæarctic Province*, including Europe, Africa north of the Atlas Mountains, and Northern Asia.

2. The *Æthopian Province*, including Africa south of the Atlas Mountains, and Southern Arabia.

3. The *Indian Province*, including Asia south of the Himalaya Mountains, Southern China, and the Indian Archipelago.

4. The *Australian Province*, including Australia, Tasmania, New Guinea, New Zealand, and a large proportion of the islands of the Pacific Ocean.

5. The *Nearctic Province*, including North America down to the centre of Mexico.

6. The *Neotropical Province*, including the whole of South America, Central America, and Southern Mexico.

The *vertical* or *bathymetrical* distribution of animals relates to the limits of depth within which each marine species of animals is confined. As a rule it is found that each species has its own definite bathymetrical zone, and that its existence is difficult or impossible at depths greater or less than those comprised by that zone. Generalising on a large number of facts, naturalists have been able to lay down and name certain definite zones, each of which has its own special fauna.

The five following zones are those generally accepted:—

1. The Littoral zone, or the tract between tide-marks.
2. The Laminarian zone, from low water to 15 fathoms.
3. The Coralline zone, from 15 to 50 fathoms.
4. The deep-sea Coral zone, from 50 to 100 fathoms.
5. To these must now be certainly added a fifth or "Abyssal" zone, extending from 100 fathoms to a depth of 3000 or 4000 fathoms.

Recent researches, however, have rendered it certain that after a certain depth, say 100 fathoms, the bathymetrical distribution of animals is conditioned not by the *depth*, but by the *temperature* of the water at the bottom of the sea. Similar forms, namely, are always found inhabiting areas in which the bottom-temperature is the same, wholly irrespective of the depth of water in the particular locality in question. The supply of food, also, and the nature of the habitat, are important elements of the case. In the light, therefore, of these recent facts, it would perhaps be advisable to adopt the views of Dr Gwyn Jeffreys, and to consider that there are only two principal bathymetrical zones—namely, the *littoral* and the *submarine*. The researches of the Challenger Expedition have also shown that at depths beyond 500 fathoms, the fauna presents essentially the same features all over the world, deep-sea genera usually possessing a cosmopolitan range.

In addition to the preceding forms of distribution, the zoologist has to investigate the condition and nature of animal life during past epochs in the history of the world.

The laws of *distribution in time*, however, are, from the nature of the case, less perfectly known than are the laws of lateral or vertical distribution, since these latter concern beings which we are able to examine directly. The following are the chief facts which it is necessary for the student to bear in mind:—

1. The rocks which compose the crust of the earth have been formed at successive periods, and may be roughly divided into aqueous or sedimentary rocks, and igneous rocks.

2. The igneous rocks are produced by the agency of heat, are mostly *unstratified* (*i.e.*, are not deposited in distinct layers or *strata*), and, with few exceptions, are destitute of any traces of past life.

3. The sedimentary or aqueous rocks owe their origin to the action of water, are *stratified* (*i.e.*, consist of separate layers or *strata*), and mostly exhibit "fossils"—that is to say, the remains or traces of animals or plants which were in existence at the time when the rocks were deposited.

4. The series of aqueous rocks is capable of being divided into a number of definite groups of strata, which are technically called "formations."

5. Each of these definite rock-groups, or "formations," is characterised by the occurrence of an assemblage of fossil remains more or less peculiar and confined to itself.

6. The majority of these fossil forms are "extinct"—that is to say, they do not admit of being referred to any species at present existing.

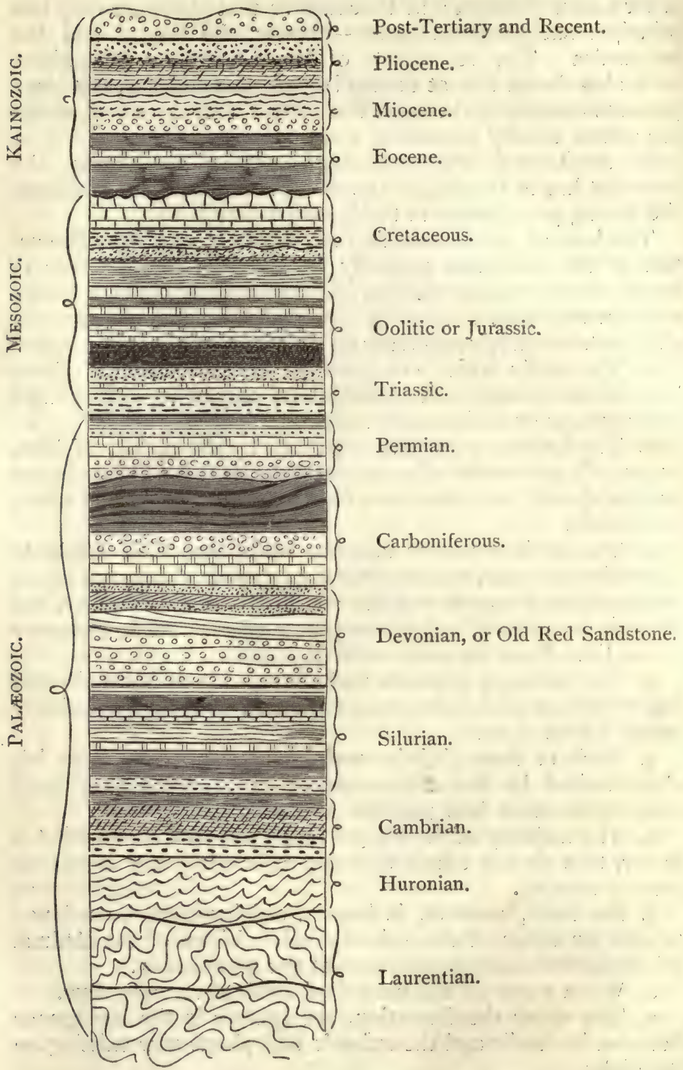
7. No fossil, however, is known, which cannot be referred to one or other of the primary subdivisions of the Animal Kingdom which are represented at the present day.

8. When a species has once died out it never reappears.

9. The older the formation, the greater is the divergence between its fossils and the animals and plants now existing on the globe.

Ideal Section of the Crust of the Earth.

Fig. 5.


Kainozoic.
Mesozoic.
Palæozoic.
Post-Tertiary and Recent.
Pliocene.
Miocene.
Eocene.
Cretaceous.
Oolitic or Jurassic.
Triassic.
Permian.
Carboniferous.
Devonian, or Old Red Sandstone.
Silurian.
Cambrian.
Huronian.
Laurentian.

10. All the known formations are divided into three great groups, termed respectively Palæozoic or Primary, Mesozoic or Secondary, and Kainozoic or Tertiary.

The Palæozoic or Ancient-life period is the oldest, and is characterised by the marked divergence of the life of the period from all existing forms.

In the Mesozoic or Middle-life period, the general *facies* of the fossils approaches more nearly to that of our existing fauna and flora; but—with very few exceptions—the characteristic fossils are all specifically distinct from all existing forms.

In the Kainozoic or New-life period, the approximation of the fossil remains to existing living beings is still closer, and some of the forms are now specifically identical with recent species; the number of these increasing rapidly as we ascend from the lowest Kainozoic deposit to the Recent period.

Subjoined is a table giving the more important subdivisions of the three great geological periods, commencing with the oldest rocks and ascending to the present day (fig. 5).

I. PALÆOZOIC OR PRIMARY ROCKS.

1. Laurentian. (Lower and Upper.)
2. Cambrian. (Lower and Upper, with Huronian rocks?)
3. Silurian. (Lower and Upper.)
4. Devonian, or Old Red Sandstone. (Lower, Middle, and Upper.)
5. Carboniferous. (Mountain-limestone, Millstone-grit, and Coal-measures.)
6. Permian. (= the lower portion of the New Red Sandstone.)

II. MESOZOIC OR SECONDARY ROCKS.

7. Triassic Rocks. (Bunter Sandstein, or Lower Trias; Muschelkalk, or Middle Trias; Keuper, or Upper Trias.)
8. Jurassic Rocks. (Lias, Inferior Oolite, Great Oolite, Oxford Clay, Coral Rag, Kimmeridge Clay, Portland Stone, Purbeck beds.)
9. Cretaceous Rocks. (Wealden, Lower Greensand, Gault, Upper Greensand, White Chalk, Maestricht beds.)

III. KAINOZOIC OR TERTIARY ROCKS.

10. Eocene. (Lower, Middle, and Upper.)
11. Miocene. (Lower and Upper.)
12. Pliocene. (Older Pliocene and Newer Pliocene.)
13. Post-tertiary. (Post-pliocene and Recent.)

INVERTEBRATE ANIMALS.

PROTOZOA.

CHAPTER I.

1. GENERAL CHARACTERS OF THE PROTOZOA. 2. CLASSIFICATION. 3. GREGARINIDA.

1. *General Characters.*—The sub-kingdom *Protozoa*, as the name implies, includes the most lowly organised members of the animal kingdom. From this circumstance it is difficult, if not impossible, to give an exhaustive definition, and the following is, perhaps, as exact as the present state of our knowledge will allow:—

The *Protozoa* may be defined as *animals, generally of minute size, composed of a nearly or altogether structureless jelly-like substance* (*termed* "*sarcode*"), *showing no composition out of definite parts or segments, having no definite body-cavity, presenting no traces of a nervous system, and having either no differentiated alimentary apparatus, or but a very rudimentary one.*

The *Protozoa* are almost exclusively aquatic in their habits, and are mostly very minute, though they sometimes form colonies of considerable size. They are composed of contractile, jelly-like protoplasm, often known by the name of "sarcode," which is semi-fluid in consistence, and is composed of an albuminous base with oil-globules scattered through it. Granules are generally developed in the sarcode, and in many cases there is a definite internal solid particle, termed the "nucleus."

In many of the *Protozoa* the protoplasm is not surrounded by a definite outer envelope, thus permanently remaining in the condition of a mere "cytode." In other cases, however (*Infusoria*), such an outer envelope exists and a central "nucleus" is present, when the organism may be compared with a single "cell" in one of the higher animals. The Sponges, again, if they are to be retained in the *Protozoa*, are "multicellular" organisms.

In no *Protozoön* are any traces known of anything like the nervous and vascular arrangements which are found in animals of a higher grade. A nervous system is universally and entirely absent, and the sole circulatory apparatus consists in certain clear spaces called "contractile vesicles," which are found in some species, and which doubtfully perform the functions of a heart. A distinct alimentary aperture is present in the higher *Protozoa*, but in many there is none; and in all, the digestive apparatus is of the simplest character. Organs of generation, or at any rate differentiated portions of the body which act as these, are sometimes present; but in many cases true sexual reproduction has not hitherto been shown to exist.

The "sarcode," which forms such a distinctive feature in all the *Protozoa*, is merely undifferentiated protoplasm, not possessing "permanent distinction or separation of parts," but nevertheless displaying all "the essential properties and characters of vitality," being capable of assimilation and excretion, of irritability and of the power of contraction, so as to produce movements, strictly analogous, in many cases, to the muscular movements of the higher animals. In some, too, the sarcode possesses the power of producing an external case or envelope, usually of carbonate of lime or flint, and often of a very complicated and mathematically regular structure.

The power of active locomotion is enjoyed by a great many of the *Protozoa;* but in some cases this is very limited, and in other cases the animal is permanently fixed in its adult condition. The apparatus of locomotion in the *Protozoa* is of a very varied nature. In many cases, especially in the higher forms, movements are effected by means of the little hair-like processes which are known as "cilia," and which have the power of lashing to and fro or vibrating with great rapidity. In other cases the cilia are accompanied or replaced by one or more long whip-like bristles, which act in the same fashion, and are known as "flagella." The most characteristic organs of locomotion amongst the lower *Protozoa* are known as "pseudopodia," and consist simply of prolongations of the sarcodic substance of the body, which can usually be emitted from the greater portion of the general surface of the body, and are capable of being again retracted, and of fusing completely with the body-substance.

2. *Classification of the Protozoa.*—The sub-kingdom *Protozoa* is divided into three classes—viz., the *Gregarinida*, the *Rhizo-*

poda, and the *Infusoria*. In the Infusoria only is a mouth present, and hence these are sometimes spoken of as the "*Stomatode*" *Protozoa*, whilst the two former classes collectively constitute the "*Astomata*."

The following is a tabular view of the divisions of the *Protozoa*:—

Class I. GREGARINIDA.

Class II. RHIZOPODA.

Order 1. *Monera*.
„ 2. *Amœbea*.
„ 3. *Foraminifera*.
„ 4. *Radiolaria*.
„ 5. *Spongida*.

Class III. INFUSORIA.

Order 1. *Suctoria*.
„ 2. *Ciliata*.
„ 3. *Flagellata*.

3. CLASS I. GREGARINIDA.—The *Gregarinida* may be defined as *parasitic Protozoa, which are destitute of a mouth, and do not possess the power of emitting "pseudopodia."* They constitute the lowest class of the *Protozoa*, and comprise certain microscopic animals which are parasitic in the alimentary canal of both Invertebrate and Vertebrate animals. They have, however, a special liking for the intestines of certain insects, being commonly found abundantly in the cockroach. As we shall see hereafter, in all probability a great deal of the degraded character of the *Gregarinida* is due to the fact that they are internal parasites, and are therefore not dependent upon their own exertions for food.

Nothing anatomically could be more simple than the structure of a *Gregarina*, since it is almost exactly that of a cell, such as the impregnated ovum (fig. 6, *b*). An adult Gregarina, in fact, may be said to be a single cell, consisting of an ill-defined membranous envelope filled with a more or less granular sarcode with fatty particles, and sometimes differentiated into a distinct contractile "cortical layer," which contains in its interior a vesicular nucleus, this in turn enclosing a solid particle, or nucleolus. In some the body exhibits an approach to a more complex structure by the presence of internal septa; but it is doubtful whether this appearance may not be due to the apposition and fusion of two separate individuals. A separate order, however, has been founded upon individuals of this kind, under the name of *Dicystidea*; the name *Monocystidea* being retained for the ordinary forms. As regards the size of the *Gregarinæ*, they vary from about the size of the head of a small pin up to as much as half an inch in length, when they assume the aspect of small worms. The integument or cuticle with which the protoplasmic body is enclosed may be quite smooth or striated, or it may be furnished with bristles or spines, or even in some cases with cilia. Sometimes one end of the body is furnished with uncinate processes, very similar in appearance to the hooked "head" of the common tape-worm (*Tænia solium*). Essentially, however, the structure of all appears to be the same. No differentiated organs of any kind beyond the nucleus and nucleolus exist, and both assimilation and excretion must be performed simply by the general surface of the body. The body is, nevertheless, contractile, and slow movements can be effected, not, however, by pseudopodia. Hæckel regards the *Gregarinæ* as *Amœbæ* which have become degenerate by parasitism; but this opinion is rejected by Van Beneden, and their apparently unicellular structure would

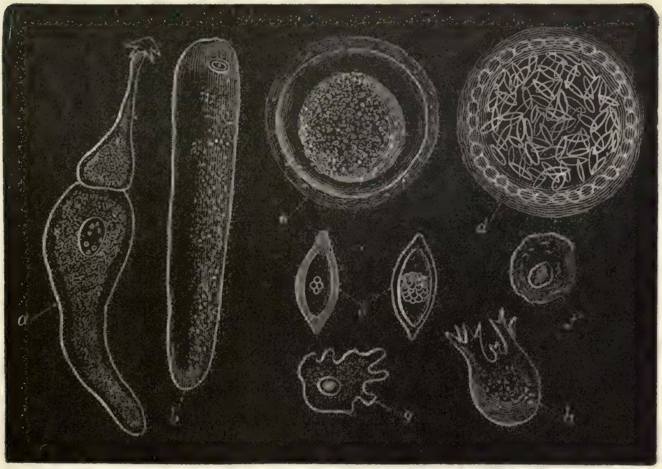


Fig. 6.—Morphology and development of *Gregarinida* (after Stein and Lieberkühn). *a Stylorhynchus oligacanthus*, a "dicystidean" Gregarine; *b* Gregarine of the earth-worm ("monocystidean"); *c* The same encysted; *d* Further stage of the same, with the contents divided into "pseudonavicellæ;" *e* Free "pseudonavicellæ;" *f* Amœbiform mass of protoplasm liberated from a pseudonavicella; *g* and *h* Active forms of *f*. All the figures are greatly enlarged.

rather lead us to place them in the neighbourhood of the *Infusoria.* The presence of muscular fibres in the cortical layer will also support the view that they should be associated with the Infusorian animalcules.

In spite of their exceedingly simple structure, the following very interesting reproductive phenomena have been observed sometimes in a single *Gregarina* without apparent cause, sometimes as the result of the apposition and coalescence of two individuals—the exact nature of the process being in either case obscure. In some species conjugation is invariable; in others it never occurs; and it may take place either by analogous or by opposite extremities. The *Gregarina*—or it may be two individuals which have come into contact and adhered together—assumes a globular form, becomes motionless, and develops round itself a structureless envelope or cyst, when it is said to be "encysted" (fig. 6, *c*). The central nucleus then disappears, apparently by dissolution, whereupon the granular contents of the cyst break up into a number of little rounded masses, which gradually elongate and become lanceolate, when they are termed "pseudonavicellæ" (or "pseudonaviculæ," fig. 6, *d*). The next step in the process consists in the liberation of the pseudonavicellæ, which escape by the rupture of the enclosing cyst (fig. 6, *e*). If they now find a congenial habitat, they give origin to little albuminous or sarcodic masses, which exhibit lively movements, and are endowed with the power of throwing out and retracting little processes of the body which closely resemble the "pseudopodia" of the *Rhizopoda;* so that the pseudonavicella in this condition is very similar to an adult *Amœba* (fig. 6, *f*, *g*, *h*). Finally, these amœbiform bodies are developed into adult *Gregarinæ.* It will be seen from the above that the formation of the pseudonavicellæ out of the granular contents of the body, subsequent to the disappearance of the nucleus, presents a close analogy to the segmentation of the impregnated ovum which follows upon the dissolution of the germinal vesicle. In *Gregarina gigantea* of the Lobster the embryo is a little mass of sarcode, quite like an *Amœba* except that it wants a nucleus and contractile vesicle. It soon gives out two little contractile processes or arms, which become detached and move about like little worms, when they are termed "pseudofilariæ," from their resemblance to free Nematoids. After a period of activity, the pseudo-filarian becomes quiescent, shortens its dimensions, develops a nucleus and nucleolus, and becomes an adult *Gregarina.*

PSOROSPERMIÆ.—There occur as parasites on and within the bodies of fishes certain vesicular, usually caudate, bodies, termed *Psorospermiæ*, the exact nature of which is very problematical. According to Lieberkühn they occasionally give origin to amœbiform bodies, similar to those which are liberated from the pseudonavicellæ of *Gregarinida.* In this case they should probably be regarded as the embryonic forms of some *Gregarina.* By Balbiani, however, they are looked upon as properly belonging to the vegetable kingdom.

CHAPTER II.

RHIZOPODA.

General Characters of the Rhizopoda.—The *Rhizopoda* may be defined as *Protozoa which are destitute of a mouth, are simple or compound, and possess the power of emitting "pseudopodia."* They are mostly small, but some of the composite forms, such as the sponges, may attain a very considerable size. Structurally, a typical Rhizopod—as an *Amœba*—is composed of almost structureless sarcode, without any organs appropriated to the function of digestion, and possessing the power of throwing out processes of its substance so as to constitute adventitious limbs. These are termed "pseudopodia," or false feet, and are usually protrusible at will from different parts of the body, into the substance of which they again melt when they are retracted. They are merely filaments of sarcode, sometimes very delicate and of considerable length, at other times more like finger-shaped processes; and they are identical with the little processes which can be thrown out by the white corpuscles of the blood and by pus-cells. Indeed, it has been remarked by Huxley that an *Amœba* is structurally "a mere colourless blood-corpuscle, leading an independent life."

The class *Rhizopoda* is divided into five orders—viz., the *Monera*, the *Amœbea*, the *Foraminifera*, the *Radiolaria*, and the *Spongida*, of which the last is occasionally considered as a separate class, or is removed entirely from the *Protozoa*.

Order I. Monera.—This name has been proposed by Hæckel for certain singular organisms which may provisionally be regarded as the lowest group of the *Rhizopoda*. They are very minute in size, and are distinguished by the fact that the body is composed of structureless sarcode, capable of emitting thread-like prolongations or pseudopodia, but destitute of either nucleus or contractile vesicle. The pseudopodia are mostly in the form of delicate filamentous processes of sarcode, which exhibit a circulation of minute molecules and granules in their interior and along their edges. Sometimes the pseudopodia may be simple, as in *Protamœba* (fig. 7, *a*), or they may be ramified and anastomosing, as in *Protogenes*. The form of the body, though very mutable, may be simple; or the organism may form a kind of colony of protoplasmic masses united by their interlacing pseudopodia (as in *Myxo-*

dictyon). Sometimes the organism passes through a quiescent stage, alternating with an active and locomotive phase of existence. No hard covering or "test" is ever developed. Reproduction is mostly by fission, with or without precedent encystation (fig. 7, *b* and *c*) and quiescence. All the *Monera* live in water, and their systematic position is uncertain. From the general nature of the pseudopodia, and the fact that the sarcode is not differentiated into an "ectosarc" and an "endosarc," they appear to be most nearly allied upon the whole to the *Foraminifera*, from which they differ chiefly in the absence of a shell defending the soft protoplasm of the body, as well as in the constant absence of a nucleus.

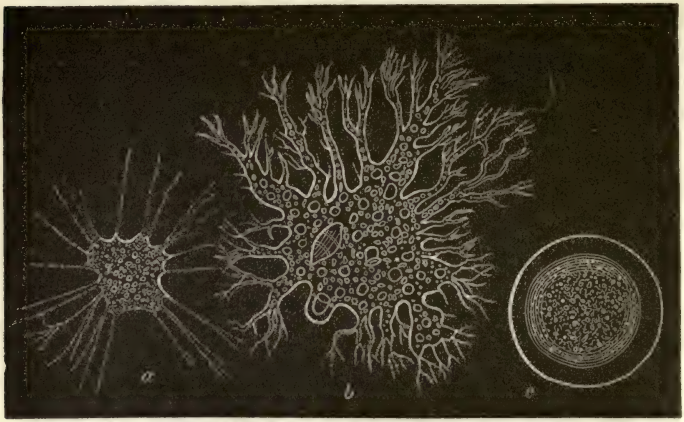


Fig. 7.—Morphology of *Monera*. *a Protamœba porrecta*; *b Protomyxa aurantiaca*; *c* The same in an encysted condition. Greatly magnified.

The name of *Bathybius* was given by Professor Huxley to a structure believed to consist of irregular, formless, diffused masses of protoplasm, without nucleus or contractile vesicle, found at great depths in the sea; and, if organic, the place of *Bathybius* would be amongst the *Monera*. More recently, however, Professor Huxley and Sir Wyville Thomson have expressed the opinion that *Bathybius* is not really a living organism at all; and it only requires mention here because a similar structure, the true nature of which still requires investigation, has recently been described by Bessels under the name of *Protobathybius*.

ORDER II. AMŒBEA.—This order comprises those *Rhizopoda which are, with few exceptions, naked; have usually short, blunt, lobose pseudopodia, which do not anastomose with* *one another; and contain a "nucleus," and one or more "contractile vesicles."*

The *Amœba*, or Proteus-animalcule, may be taken as the type, and a description of it will be sufficient to indicate the leading points of interest in the order. The *Amœba* (fig. 8, B) is a microscopic animalcule, which inhabits fresh water,* and is composed of gelatinous sarcode, which admits of a separation into two distinct layers: an outer transparent layer, termed the "ectosarc;" and an inner, more fluid and mobile, molecular layer, called the "endosarc." The "ectosarc" is highly extensile and contractile, and is the layer of which the pseudopodia are mainly composed; whilst the "endosarc" contains the only organs possessed by the animal—viz., the "nucleus" and "contractile vesicle" or vesicles, along with certain fortuitous cavities termed "food-vacuoles."

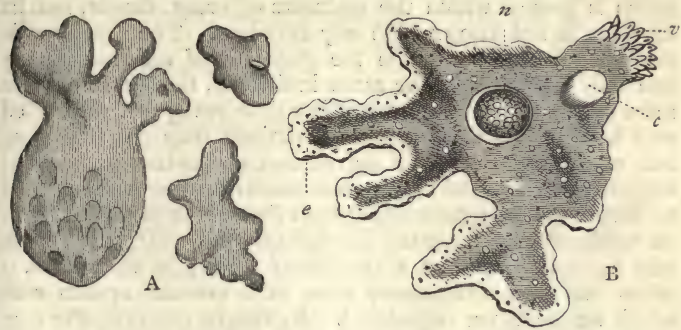


Fig. 8.—A, *Amœbæ* developed in organic infusions (after Beale), greatly enlarged; B, *Amœba princeps* (after Carter); *v* Villous region; *c* Contractile vesicle; *n* Nucleus; *e* Ectosarc.

It is believed by some that the ectosarc is surrounded by a colourless and structureless investing membrane or cuticle; but this is denied by others. Be this as it may, there is no oral aperture, so far as has ever been certainly observed, and the food is merely taken into the interior of the body by a process of intussusception—any portion of the surface being chosen for this purpose, and acting as an extemporaneous mouth. When the particle of food has been received into the body, the aperture by which it was admitted again closes up, and the discharge of solid excreta is effected in an exactly similar manner.

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* Greeff has shown that some species of *Amœba* (such as *A. terricola*) inhabit moist sand or earth.

In this case, however, the area of the general surface within which an anus may be extemporised, appears to be more restricted, and to comprise a portion only of the body ("villous region").

The "nucleus" (fig. 8) is a solid granular body, or a clear vesicle containing a "nucleolus" in its interior, one or more of which is present within the endosarc of every *Amœba*, but its function is not known with any certainty. The "contractile vesicles" are cavities within the endosarc, of which ordinarily one only is present in the same individual, though sometimes there are more. In structure it is a little cavity or vesicle filled with a colourless fluid apparently derived from the digestion, and exhibiting rhythmical movements of contraction (*systole*) and dilatation (*diastole*). In some cases radiating tubes are said to have been seen proceeding from the vesicle at the moment of contraction. Regarded functionally, the contractile vesicle may be looked upon as a circulatory organ; in which case, it offers the most rudimentary form of a vascular system with which we are as yet acquainted. By others, however, the contractile vesicle is believed to be filled with water from the exterior, and it is regarded as a rudimentary form of *water-vascular* system; while others regard it as an excretory organ.

Besides these proper organs, the endosarc usually contains clear spaces, which are called "vacuoles," or, more properly, "food-vacuoles." These spaces (though sometimes rhythmically contractile) are of a merely temporary character, and are simply produced by the presence of particles of food, usually with a little water taken into the body along with the food.

There are no traces of any organs of sense, or of a nervous system, or, indeed, of any other organs in addition to those already described. Locomotion is effected with moderate activity, but in an irregular manner, by means of the blunt, finger-shaped processes of sarcode, or pseudopodia, which can be protruded at will from any part of the body, and can be again retracted within it. The pseudopodia also serve as prehensile organs; but they do not interlace and form a network, nor do they exhibit any circulation of granules derived from the endosarc, as in many others of the *Rhizopoda*.

As regards the reproductive process in the *Amœba*, no differentiated sexual organs have hitherto been discovered, and the true sexual form of the process is therefore unknown. Fresh individuals, however, may be produced in three ways: *Firstly*, by simple fission, the animal dividing into two parts, each of which becomes an independent organism. *Secondly*, by the detachment of a single pseudopodium, which becomes developed into a fresh *Amœba*. *Thirdly*, by the production of little spherical masses of sarcode, which may be derived from the nucleus by fission, or may be produced by a segmentation of the endosarc, the animal having previously become torpid, and the nucleus and contractile vesicle having disappeared. These little masses, however produced, develop themselves when liberated into ordinary *Amœbæ*. This last method of reproduction is obviously very closely analogous to the production of "pseudonavicellæ" in an encysted *Gregarina*.

The remaining members of the *Amœbea* are constructed more or less closely after the type of the *Amœba* itself. In the nearly allied *Difflugia*, the sarcode forming the body of the animal is invested with a membranous envelope or "carapace," strengthened by grains of sand and other adventitious solid particles, and having a single aperture at one extremity, through which the pseudopodia are protruded (fig. 9). The animal generally creeps about head-downwards, so to speak; that is to say, with the closed end of the carapace elevated above the surface on which it is moving. *Difflugiæ* often exhibit the phenomenon known as "conjugation" or "zygosis." Under these circumstances, two *Difflugiæ* come in contact; the mouths of the two tests are brought together; the two animals flow backwards and forwards into each other's tests, with an apparently complete incorporation; and finally they separate again, and each retires to its own test. In *Arcella* there is a discoid or basin-shaped carapace, secreted by the animal itself, and likewise possessing but a single pseudopodial aperture, placed in this case on the flat surface of the body. One species of *Arcella* (viz., *A. arenaria*) is terrestrial in its habits.

In *Pamphagus* there is no carapace, but the pseudopodia are nevertheless protrusible from one extremity only of the body, the remainder of the surface appearing to be of too resistant a consistence to allow of this. *Cochliopodium* is like *Arcella*, but the test is quite flexible. *Pseudochlamys*, *Hyalosphenia*, *Quadrula*, &c., are other fresh-water Rhizopods more or less closely allied to *Arcella* and *Difflugia*, but often exhibiting interesting and remarkable modifications of structure.

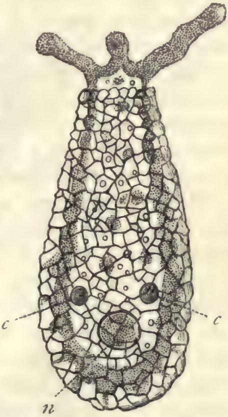

Fig. 9.—*Difflugia pyriformis*, greatly enlarged. (Altered slightly from Carter.) The test is composed of angular grains of transparent quartz, within which is the transparent ectosarc, lined by the finely granular endosarc. *n* Nucleus; *c c* Contractile vesicles.

The *Amœbea* may be divided into two sub-orders: 1. *Amœbina*, including those forms which have the body naked; and 2. *Arcellina*, comprising those in which the body is protected by a carapace. The latter are included by Hertwig and Lesser along with *Gromia* and the typical *Foraminifera* in a common group, to which they give the name of *Thalamophora*. The blunt and lobose character of the pseudopodia in the *Arcellina* would, however, appear to be a more important character than the possession of a test, and would assign to these forms a position close to *Amœba.*

CHAPTER III.

FORAMINIFERA.

Order III. Foraminifera.—The *Foraminifera* may be defined as *Rhizopoda in which the body is protected by a shell or "test," composed of carbonate of lime, or of sand-grains cemented together, or, rarely, of chitine; there is no distinct separation of the sarcode of the body into ectosarc and endosarc, and a nucleus and contractile vesicle are present in at any rate some cases. The pseudopodia are long and filamentous, and interlace with one another to form a network.*

The *Foraminifera* are specially characterised by the possession of a "test" or external shell, which is usually composed of carbonate of lime, but is often composed of grains of sand or other adventitious solid particles cemented together by animal matter, or which, as in *Gromia*, may be simply chitinous. The test may be composed of an aggregation of chambers or "loculi" (fig. 11, *c*), or of a single chamber only, and its walls are usually pierced by numerous pores or "foramina" through which the pseudopodia are protruded; the place of these being in other forms supplied by the large size of the terminal, or "*oral*," aperture of the shell (fig. 10, *b*), the walls themselves being imperforate. The presence or absence of foramina in the shell-walls is believed to constitute a genuine structural distinction, and the *Foraminifera* may be thereby divided into two great groups (*Perforata* and *Imperforata*).

As regards the soft parts of the *Foraminifera*, the body is composed of extensile and contractile sarcode—usually reddish or yellowish in colour—which not only fills the interior of the shell, but generally invests its outer surface also with a thin film, from which the pseudopodia are emitted (fig. 10, *b*). The test, therefore, in this case, is not a true cuticular secretion, like that of the *Mollusca*, but it is truly immersed within the sarcode of the body. The sarcode is not differentiated into a distinct ectosarc and endosarc, and until recently was believed to be devoid of a nucleus and contractile vesicle, and, indeed, of any organs or specialised parts of any kind. Recent researches, by Hertwig and F. E. Schultze, have, however, shown

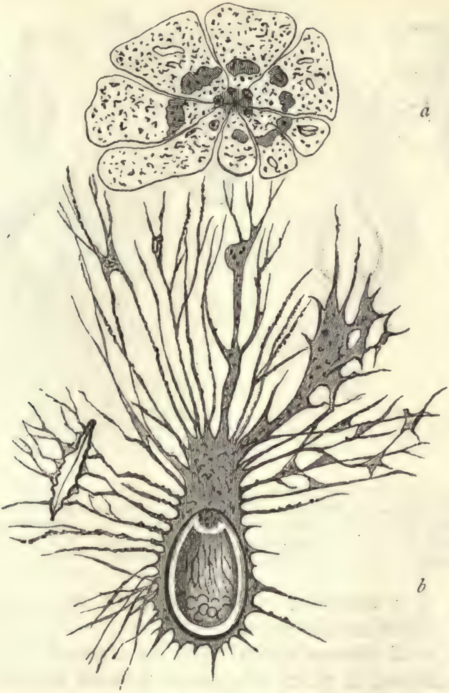

Fig. 10 —Foraminifera. *a* The animal of *Nonionina*, after the shell has been removed by a weak acid; *b Gromia* (after Schultze), showing the shell surrounded by a network of filaments derived from the body-substance.

the presence of a nucleus and of contractile vesicles in, at any rate, some of the *Foraminifera;* and these structures are, therefore, probably present in all. Even in the polythalamous forms there seems to be, as a rule, only one nucleus, so that the organism morphologically may be regarded as a single cytode.

The pseudopodia in all the *Foraminifera* (fig. 11, *b*, *c*) are filamentous and protrusible to a great length and they possess the singular property of uniting together in various directions so as to form a kind of network, like an "animated spider's web." (Hence the name *Reticulosa* applied to the order by Dr Carpenter.) This property, however, is not peculiar to members of this order, but is seen also in *Actinophrys* and in the *Thalassicollida*, though to a less extent. Further, throughout the entire network formed by the inosculating pseudopodia there is a constant circulation of minute protoplasmic granules in different directions.

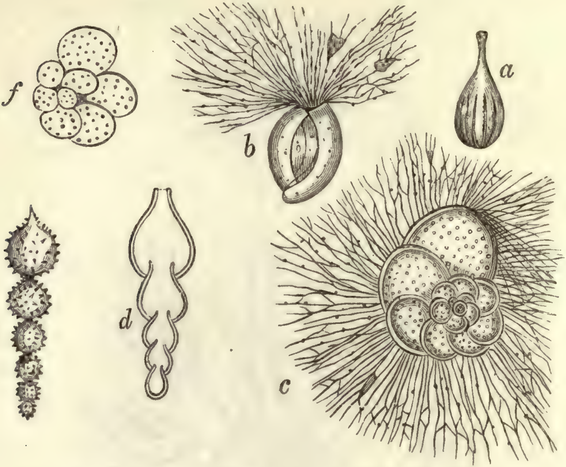

Fig. 11.—Morphology of Foraminifera. *a Lagena vulgaris*, a monothalamous Foraminifer; *b Miliola* (after Schultze), showing the pseudopodia protruded from the oral aperture of the shell; *c Discorbina* (after Schultze), showing the nautiloid shell with the foramina in the shell-wall giving exit to pseudopodia; *d* Section of *Nodosaria* (after Carpenter); *e Nodosaria hispida; f Globigerina bulloides.*

The shells of *Foraminifera* may be classed, according to their composition, in three divisions, termed respectively the "porcellanous," the "hyaline" or "vitreous," and the "arenaceous." The porcellanous shell is calcareous and quite homogeneous in its composition, is opaque-white when seen by reflected light, and is not perforated by pseudopodial foramina. In these forms (*e. g.*, *Miliola*, fig. 11, *b*) the pseudopodia are emitted solely from the mouth of the last-formed segment of the shell. The vitreous shell is also calcareous in composition, but is transparent and glassy in texture, and its walls are perforated by numerous pseudopodial apertures. The arenaceous *Foraminifera* (fig. 12) are among the largest of the living types, the test being sometimes half an inch or more in length. In its nature, the test is normally composed of siliceous particles embedded in an apparently chitinous matrix, with a notable proportion of peroxide of iron and a small percentage of carbonate of lime (H. B. Brady). It should be noted, however, that the test of *Miliola*, though normally calcareous and porcellanous, has been shown by Mr H. B. Brady to occasionally assume arenaceous characters, or even, when obtained from very great depths, to be composed of pure hyaline silica. It would appear, therefore, that the composition of the shell is liable to variation, in accordance with the nature of the materials obtainable at any particular station by the organism, so that too great stress cannot be laid upon this character in classification. As a rule, the arenaceous test is imperforate, and the pseudopodia are emitted by the terminal aperture of the shell; but cases are not unknown in which the walls are porous. Finally, there is a group of forms in which the test (as in *Gromia*) is composed simply of chitine.

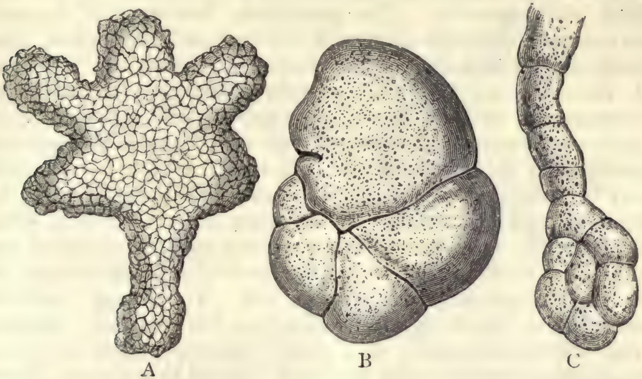

Fig. 12.—Shells of Arenaceous Foraminifera. A, Test of *Astrorhiza*, greatly enlarged; B, Test of *Trochammina ringens*, enlarged thirty times; C, Test of *Trochammina lituiformis*, enlarged eighteen times. (After Carpenter and Brady.)

In some of the *Foraminifera*, hence called "simple" or "unilocular" (*Monothalamia*), the shell consists of a single chamber, and the animal is, in fact, nothing more than a little mass of sarcode enveloped in a calcareous covering. *Lagena* (fig. 11, *a*) with its beautiful flask-shaped shell, may be taken as the type of this division. Another well-known unilocular form is *Entosolenia*, which is like *Lagena* in shape, but has the tubular neck reversed, so as to be inserted into the interior of the test. In the more complex *Foraminifera*, the sarcode of the body undergoes a subdivision into partially separated segments, which may be produced by a process of budding, or, perhaps, by the occurrence of constrictions in the growing protoplasm, and each of these segments becomes more or less completely divided off from its neighbours, or enclosed by a wall of shell. In these "multilocular" or "polythalamous" *Foraminifera*, therefore, the shell ultimately comes to consist of a series of chambers, separated by partitions of the test, and filled with sarcode. The partitions, however, or "septa," between the different chambers, are perforated by one or more apertures, through which pass connecting bands, or "stolons," of sarcode; so that the sarcode occupying the different chambers is united into a continuous and organic whole. Each segment may give out its own pseudopodia through perforations in its investing wall (fig. 11, *c*), or the pseudopodia may be simply emitted from the mouth of the shell by the last segment only (fig. 11, *b*). In any case the direction in which the segments are developed is governed by a determinate law, and differs in different species, the form ultimately assumed by the shell depending wholly upon this. The forms, however, assumed by the shells of *Foraminifera* are extremely variable, even within the limits of a single species, and it would be impossible to notice even the chief types in this place. There are, however, two or three important variations which may be noticed. If the buds are thrown out from the primitive spherule in a linear series so as to form a shell composed of numerous chambers arranged in a straight line, we get such a type as *Nodosaria* (fig. 11, *e*). When the new chambers are added in a spiral direction, each being a little larger than the one which preceded it, and the coils of the spiral lying in the same plane, we get such a form as *Discorbina* (fig. 11, *c*), or *Robulina*. These are the so-called "nautiloid" *Foraminifera*, from the resemblance of the shell, in figure, to that of the Pearly Nautilus. From this resemblance the nautiloid *Foraminifera* were originally placed in the same class as the *Ammonites* (*Cephalopoda*), but their true position was shown by the examination of their soft parts. In the typical nautiloid shell the convolutions of the spiral all lie in one plane; but in other cases, as in *Rotalia*, the shell becomes turreted or top-shaped, in consequence of the coils of the spiral passing obliquely round a central axis.

In a few types of the *Foraminifera* (*e.g.*, in the *Dactyloporidæ*) the successive chambers of the multilocular test have no direct communication with one another, and simply cohere by their walls. In the majority of the compound shells, the successive chambers are so produced, that the septum between any two of them is formed solely by the anterior wall of the older chamber, which thus constitutes the posterior wall of the newer one (fig. 11, *e*). In the highest types of the compound *Foraminifera*, however, each segment is provided with its own proper wall of shell, each segment, as it is produced, forming for itself a posterior wall which applies itself to the anterior wall of the preceding segment, so that each septum ("septal plane") is composed of *two* lamellæ, as seen in fig. 13, A (Carpenter). Moreover, "in the higher types of the hyaline or vitreous series we frequently meet with an 'intermediate' or 'supplemental' skeleton, formed by a secondary or exogenous deposit upon the outer walls of the chambers, by which they receive a great accession of strength. This deposit not only fills up what would otherwise be superficial hollows at the junctions of the chambers (fig. 13, A, *d*), or (as in *Polystomella*) at the umbilical depression, but often forms a layer of considerable thickness over the whole surface, thus separating each whorl from that which encloses it; and it is sometimes prolonged into outgrowths that give a very peculiar variety to the ordinary contour, as in some varieties of *Rotalia* and *Polystomella*, but most characteristically in *Calcarina* (fig. 13, B). This intermediate or supplemental skeleton, wherever developed to any considerable extent, is traversed by a set of 'canals,' which are usually arranged upon a systematic plan, and are sometimes distributed with considerable minuteness" (Carpenter). The canals of this system are doubtless filled in the living state by prolongations of the sarcode, which serve to keep up the vitality of the intermediate skeleton. This intermediate skeleton, with its canal-

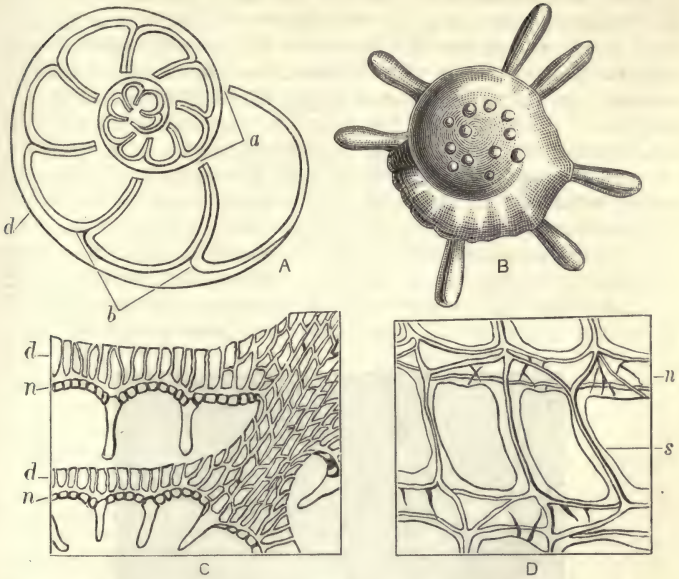

Fig. 13.—A, Diagram of one of the higher forms of the vitreous *Foraminifera*, showing the double nature of the septa (*b*), the stolon-passages between successive chambers (*a*), and the supplemental skeleton (*d*); B, Test of *Calcarina Spengleri*, magnified twelve diameters, showing the spines formed by the supplemental skeleton; C, Part of a section of the test of *Calcarina*, magnified fifty diameters, showing the tubulated "proper walls" of the chambers (*n*), and the canal-system of the intermediate skeleton (*d*); D, Part of the test of *Nummulina lævigata*, highly magnified, showing the canal-system of the septa (*s*), and marginal cord (*n*). (After Carpenter.)

system, is largely developed in many of the highest and largest of the types of the Hyaline *Foraminifera* (such as *Nummulina*), and very specially so in the ancient *Eozoön*, if this be rightly regarded as a Foraminifer.

The recognition of a "nucleus" in many *Foraminifera*—and its probable presence in all—renders it necessary to unite with this group a number of fresh-water Rhizopods, which would otherwise have to be placed with the *Amœbea*, and to which we may, in a restricted sense, apply Hertwig's name of *Thalamophora.** The test in the forms in question is always one-chambered, and in all except *Diaphorophodon* it is imperforate. It may be smooth or sculptured, and in composition it may be either membranous or chitinous, in some cases with adventitious siliceous particles in addition. Both a nucleus and contractile vacuoles are present in the protoplasm of the body; and the pseudopodia are long and filamentous or reticulated. Of these simple "Reticularian" Rhizopods, *Gromia* (fig. 10, *b*) is both a marine and a fresh-water form, and possesses a delicate membranous test, from a terminal aperture in which the protoplasm gains the exterior. *Microgromia* (fig. 14) resembles

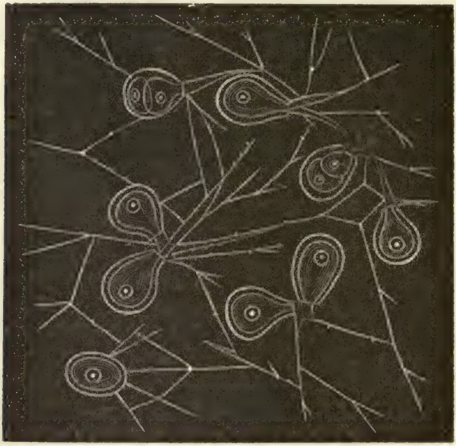

Fig. 14.—A colony of *Microgromia socialis*, showing the different members of the colony united by their branching pseudopodia. Greatly enlarged. (After Hertwig.)

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* Under the name *Thalamophora*, Hertwig and Lesser include the true *Foraminifera*, the monothalamous Rhizopods above alluded to (with "reticularian" pseudopodia), and the *Arcellina*. The last of these, however, on account of their blunt, lobose pseudopodia, are here placed in the order of the *Amœbea*.

Gromia in structure, but forms loose colonies by the root-like union of the pseudopodia of a number of individuals. It lives in fresh water, and reproduces itself by giving exit to amœboid masses of protoplasm, each of which develops two flagella, thus constituting free locomotive "swarm-spores." *Euglypha* and *Diplophrys* are other forms allied to *Gromia*, the former having an inflexible and sculptured test, while the latter has two oppositely-placed apertures in the shell, in place of a single terminal opening.

CHALLENGERIDA.—In the neighbourhood of *Gromia* we may, perhaps, place the singular marine *Rhizopods* which Sir Wyville Thomson has raised to the rank of a distinct order under the name of *Challengerida*, from the type-genus *Challengeria.* This group comprises minute Rhizopods enclosed in a monothalamous test of silica, the form of which varies, being globular, lenticular, flask-shaped, or triangular. The surface of the shell is usually sculptured, often with deeply sunk pits, and there is a single pseudopodial aperture, "usually guarded by a beautifully-formed and frequently highly-ornamented lip"—('The Atlantic,' vol. ii. p. 341). The sarcode in the interior of the test is granular, with one or more nuclei, and with a number of brown or nearly black, compound, granular bodies.

CLASSIFICATION OF THE FORAMINIFERA.—The classification of the *Foraminifera* has proved a matter of considerable difficulty. The older arrangements were unnatural, as being based wholly on the form of the shell, a point in which the *Foraminifera* show a most marvellous variability. For this reason the artificial systems proposed by D'Orbigny and Max Schultze have now been generally abandoned, and their place has been taken by the schemes of classification put forward independently and almost simultaneously by Professor Von Reuss upon the Continent, and by Dr Carpenter, Mr Parker, and Professor T. Rupert Jones in this country. Both these arrangements agree in the essential feature that they divide the *Foraminifera* into two great primary divisions, in accordance with the nature of the shelly investment. In the one division (*Imperforata*), the test is not perforated by pseudopodial apertures, and it may be either "arenaceous" or "porcellanous." In the other division the test is perforated by more or less numerous pseudopodial foramina, and to this division the name of *Perforata* is applied. The following tables exhibit the arrangements proposed by Carpenter, Parker, and Rupert Jones, on the one hand, and Reuss, on the other hand; the former being the most natural, and the one most widely adopted:—

CLASSIFICATION OF THE FORAMINIFERA, ACCORDING TO CARPENTER, PARKER, AND RUPERT JONES.

SUB-ORDER I. IMPERFORATA.—Test membranous, calcareous, or arenaceous, not perforated by pseudopodial foramina.

Family 1. *Gromida.*
" 2. *Miliolida.*
" 3. *Lituolida.*

SUB-ORDER II. PERFORATA.—Test perforated by pseudopodial foramina, generally calcareous.

Family 1. *Lagenida.*
" 2. *Globigerinida.*
" 3. *Nummulinida.*

CLASSIFICATION OF THE FORAMINIFERA ACCORDING TO REUSS.

I. FORAMINIFERA WITH A NON-PERFORATE TEST.

A. With arenaceous tests.

1. *Lituolidea.*
2. *Uvellidea.*

B. With compact, porcellanous, calcareous tests.

1. *Squamulinidea.*
2. *Miliolidea.*
3. *Peneroplidea.*
4. *Orbitulitidea.*

II. FORAMINIFERA WITH A PERFORATE TEST.

A. With glassy, finely porous, calcareous tests.

1. *Spirillinidea.*
2. *Ovulitidea.*
3. *Rhabdoidea.*
4. *Cristellaridea.*
5. *Polymorphinidea.*
6. *Cryptostegia.*
7. *Textilaridea.*
8. *Cassidulinidea.*

B. With an exceedingly porous, calcareous test.

1. *Rotalidea.*

C. With a calcareous shell, traversed by a ramified canal-system.

1. *Polystomellidea.*
2. *Nummulitidea.*

With regard to the classification of the *Foraminifera*, the author may be excused for quoting some remarks on this subject made by Mr Henry Bowman Brady, F.R.S., one of the highest living authorities on this group of organisms; since they not only have a most important bearing upon the special point in question, but forcibly express the principles which should guide the philosophic naturalist in his systematic treatment of all such variable forms of life:* "A purely artificial classification is ill adapted to the conditions presented by a class of organisms like the *Foraminifera*, largely made up of groups of which the modifications run in parallel lines. This 'isomorphism,' demonstrated chiefly by the labours of Messrs Parker and Jones, whilst it is the source of most of the difficulties the systematist has to contend with, is, at the same time, the key to the natural history of the order. It exists not merely between a single series, in one of the larger divisions, and a single series in another, but often amongst several series even of the same family. It not unfrequently happens that a member of one group presents a greater similarity to its isomorph in another group with which it has no relationship, than it does to any other member of its own group. Take a familiar illustration—suppose the fingers of the two hands to represent the modifications ('species') of two such parallel types of *Foraminifera:* the thumb of one hand resembles more closely the thumb of the other hand than it does any other of the fingers on its own. In other words, the extreme member of one series resembles more closely its isomorph in the other series than it does its own nearer relations, and so on through the remaining members of the respective groups. Under conditions like these, artificial subdivision, based upon minor morphological characters, is certain to infringe the order of nature. Its tendency is to separate forms closely allied, and in many cases to place together such as have no close affinity."

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* The remarks here quoted are taken from the introduction to Mr Brady's admirable 'Monograph of the Carboniferous Foraminifera of Great Britain.'

DISTRIBUTION OF FORAMINIFERA IN SPACE.—The *Foraminifera* (save *Gromia*, which occurs in both fresh and salt water, and the fresh-water forms allied to this) are marine, and are found in almost all seas, though more abundantly in those of the warmer parts of the globe. It is concluded by Dr Carpenter that "the foraminiferous *fauna* of our own seas probably presents a greater range of variety than existed at any preceding period; but there is no indication of any tendency to elevation towards a higher type." One of the most remarkable facts about their distribution at the present day, is the existence of a deposit at great depths in the Atlantic and Pacific oceans, in areas traversed by warm currents, of a mud or "ooze" formed almost entirely of the shells of *Foraminifera*, and principally of *Globigerinæ* (fig. 15). This "Globigerina ooze" is found up to depths of 3000 fathoms, and may be regarded as the modern analogue of the white Chalk of the Cretaceous period. The deep-sea dredgings of late years have further brought to light an immense number of forms of "arenaceous" *Foraminifera* of the most varied and interesting characters. Some of the living *Foraminifera* may be obtained, at or near low-water mark, adhering to the roots of tangle; but they are mostly to be obtained by dredging in deeper water, or by the tow-net, or by search in the shelly sand of the sea-shore.

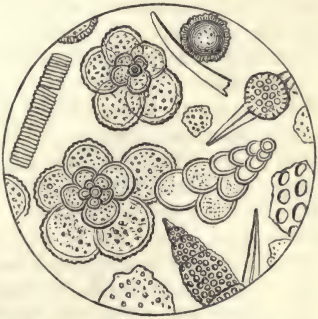

Fig. 15.—Organisms in the Atlantic ooze, chiefly *Foraminifera* (*Globigerina* and *Textularia*), with *Polycystina*, and Sponge-spicules; highly magnified. (Original.)

Most of the recent *Foraminifera* are very minute, often wholly microscopic in their dimensions; but some of the extinct forms attained the size of as much as three inches in circumference (*e.g.*, the Nummulites of the Eocene, fig. 16), and the spheres of the Cretaceous *Parkeria* may have a circumference more than twice as great as this.

DISTRIBUTION OF FORAMINIFERA IN TIME.—Remains of *Foraminifera* have been found in Palæozoic, Mesozoic, and Kainozoic formations. In the oldest stratified rocks with which we are acquainted—viz., the Laurentian rocks of Canada—there occurs a singular body which has been described as the remains of a gigantic *Foraminifer*, under the name of *Eozoön Canadense.* If truly organic, as is doubted by high authorities, it is the oldest fossil as yet discovered. It appears to have grown in reef-like masses resembling the sessile patches of *Polytrema** and *Calcarina*, to both of which, as well as to the extinct *Nummulites*, it shows a decided affinity. In the Silurian rocks, remains of *Foraminifera*, some of which are apparently identical with existing genera, have been detected in various places, and it is not impossible that the large Silurian fossils known as *Receptaculites* and *Stromatopora* should really be referred to this order. Little is yet known of the *Foraminifera* of the Devonian period; but the remains of these organisms are found abundantly in the Carboniferous, and less plentifully in the Permian deposits. Whole beds of the Carboniferous Limestone in Russia, Armenia, N. America, &c., are made up of the shells of *Fusulina;* and in Britain Mr Brady has shown that the same formation is occasionally largely composed of the arenaceous spheres of *Saccammina*, a genus which is especially interesting, as Sars has found vast numbers of a living form at considerable depths in the North Sea, and as it is known to occur in rocks as old as the Lower Silurian. In the Secondary rocks *Foraminifera* occur in great abundance, the widely spread formation known as the Chalk being crowded with these organisms. Chalk itself, in fact, is very largely composed of the cases of *Foraminifera*, some of which are identical with species now existing.

In the Tertiary rocks the *Foraminifera* attain their maximum of development, both as regards the size and the number of the forms which characterise them. The period of the Middle

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* *Polytrema* is a little branched coral-like Foraminifer, composed of a calcareous test forming a number of irregular chambers, which communicate with one another by wide orifices, and are filled with colourless sarcode. The walls of the chambers are also penetrated by an extensive system of capillary canals.

Eocene is especially distinguished by a very widely spread and easily recognised rock known as the Nummulitic Limestone, so called from the abundance in it of a large coin-shaped *Foraminifer* termed the *Nummulite* (fig. 16). The Nummulitic Limestone stretches from the west of Europe to the frontiers of China; but in some cases, in place of *Nummulina* proper, it contains the remains of a mimetic form termed *Orbitoides*. Upon the whole, Dr Carpenter concludes that "there is no evidence of any fundamental modification or advance of the foraminiferous type from the Palæozoic period to the present time."

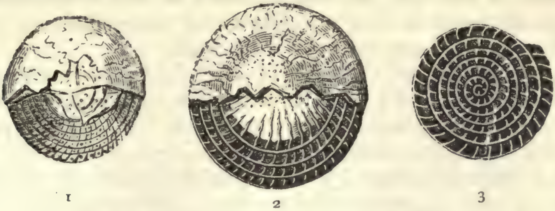

Fig. 16.—*Nummulina lævigata.* Eocene.

CHAPTER IV.

RADIOLARIA.

ORDER IV. RADIOLARIA.—The order *Radiolaria* was founded by Müller to include the *Polycystina*, the *Acanthometrina*, and the *Thalassicollida*, to which Dr Carpenter adds *Actinophrys* and its allies, chiefly on account of the form of the pseudopodia, the latter forming a special group, to which the name of *Heliozoa* may be given. Most of the *Radiolaria* are marine, and the few forms which have been described as occurring in fresh water, are probably best referred to the *Heliozoa*.

The order *Radiolaria* may be defined as comprising those *Rhizopods which generally possess a siliceous test or siliceous spicules, and are provided with pseudopodia which stand out like radiating filaments, and occasionally run into one another. All of the typical Radiolaria possess a central membranous or chitinous capsule surrounded by an envelope of sarcode. The extra-capsular sarcode generally contains a layer of yellow cells, which are composed partly of starch.* If we except *Actinophrys* and its allies—

which cannot be regarded as typical members of the order—no contractile vesicle is present. In the aberrant *Myxobrachia*, also, the characteristic radiating pseudopodia are absent, the organism being furnished with from one to sixteen arm-like processes of sarcode, the clavate ends of which enclose numerous calcareous bodies (coccoliths and coccospheres), which may, however, be simply taken in as food.

The protoplasm of the body of a Radiolarian consists typically of a central and a peripheral portion, of which the former is enclosed in a porous, membranous, or chitinous capsule, while the latter is surrounded by a gelatinous investment. In the often brightly coloured extra-capsular sarcode are scattered the yellow cells above alluded to, which some regard as being truly of a parasitic nature. The pseudopodia (fig. 17), are numerous, filamentous, radiately disposed, and sometimes anastomosing. Skeletal structures, in the form of spicular, radiating spines, or fenestrated shells, may be developed in either the extra-capsular or the intra-capsular sarcode, or in both. These skeletal structures may be wanting; but, when present, they are almost always siliceous, rarely horny, never calcareous. The animal is usually simple, varying in size from $\frac{1}{600}$ to $\frac{1}{20}$ inch, or rarely more, but in other cases (*Collozoum*) colonies are formed, which may reach two inches in diameter.

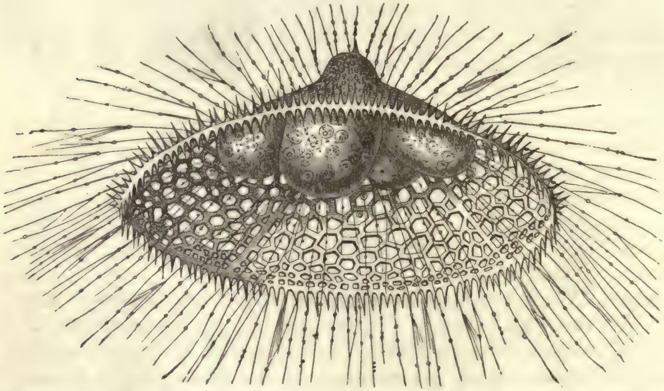

Fig. 17.—*Eucecryphalus Schultzei*, with the pseudopodia extended, showing the perforated siliceous test and the lobed protoplasmic body. After Kölliker. (The author is indebted to the kindness of Professor Mivart for the use of this engraving.)

Reproduction is often by fission; but in other cases the intra-capsular sarcode breaks up into minute germs or zoöspores, each of which possesses a nucleus and a flagellum.

The following are the more important groups of the *Radiolaria* :—

I. Family Acanthometrina.—The *Acanthometræ* (fig. 18, *a*) are all minute, and are found floating near the surface in the open ocean, sometimes in great numbers. They consist of sarcode-bodies, which are supported by a framework of radiating siliceous, or horny spines, the extremities of which usually project considerably beyond the body. The substance of the body admits of division into an outer membranous layer, or "ectosarc," and an internal granular layer, or "endosarc." The siliceous spines are hollow, being grooved at the base by a gutter, which is continued further up the spine by a canal terminating at the apex of the spine by a distinct aperture. The spines, in consequence of this structure, are able to serve for the transmission of the pseudopodia, which gain the exterior by running through the canals and escaping at their apices. Many of the pseudopodia, however, do not occupy the canals of the spines.

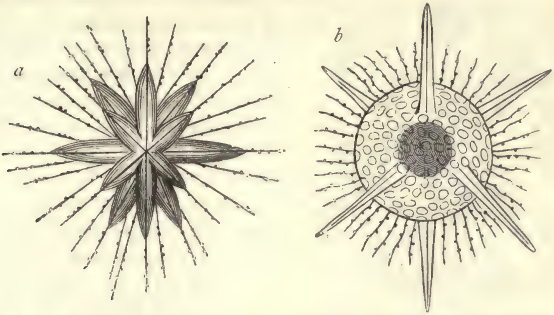

Fig. 18 —*a Acanthometra lanceolata; b Haliomma hexacanthum*, one of the *Polycystina*, showing the radiating pseudopodia. (After Müller.)

II. Fam. Polycystina.—The members of this family are closely related to the *Foraminifera*, differing from them chiefly in the fact that their shells are composed of flint instead of carbonate of lime, as in most of the latter. They possess a body of sarcode, which is enclosed in a foraminated siliceous shell, which is often furnished with spine-like processes, and is usually of great beauty (figs. 17 and 18, *b*). The sarcodic substance of the body is olive-brown in colour, with yellow globules, and often does not entirely fill the shell. The pseudopodia are emitted through the foramina in the test, and are long, ray-like filaments, which display a slow movement of granules along their borders.

The *Polycystina* are all microscopic, and are all inhabitants of the sea, having a very wide distribution. They likewise extend to great depths; and one of the numerous facts of interest brought to light by the researches of the Challenger Expedition, under Sir Wyville Thomson, has been that large areas of the sea-bottom, up to the enormous depth of 4500 fathoms, are formed by an "ooze" composed of the siliceous cases of *Polycystina* and other Radiolarians. Similar deposits of Tertiary age are known as occurring in the crust of the earth in various regions. One of the best known of these is the "Barbadoes Earth" (fig. 19), which is almost wholly composed of the delicate flinty shells of the *Polycystina*. The remains of *Polycystina* have also now been detected in rocks as old as the Jurassic formation.

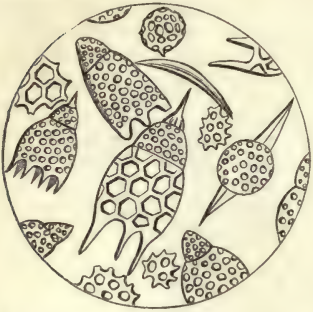

Fig. 19.—Shells of *Polycystina* from the "Barbadoes Earth;" greatly magnified. (Original.)

III. Fam. Collozoa.—In this family the organism is usually compound, though occasionally simple. A skeleton may be wholly wanting (as in the composite *Collozoum*), or may exist in the form of spicules or of a foraminated shell. The simple types always possess a mere spicular skeleton, and the same is true in such forms as *Sphærozoum* (fig. 20, *b*). On the other hand, in such forms as *Collosphæra* (fig. 20, *a*) there is a spheroidal fenestrated test, the skeleton thus approximating in character to that of the *Polycystina*. The members of this

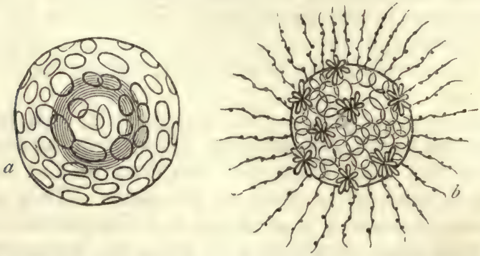

Fig. 20. — Morphology of Radiolaria. *a* Siliceous fenestrated test of *Collosphæra Huxleyi*; *b* *Sphærozoum morum*, showing cellæform bodies, compound groups of spicules, and radiating pseudopodia.

family sometimes attain a considerable size, and are found floating near the surface in most seas.

IV. FAM. THALASSICOLLIDA.—This family, as now restricted, comprises floating marine organisms, which are in many respects closely allied to the preceding, but in which the intra-capsular sarcode contains a complex nucleus. The skeleton may be wanting (as in *Thalassicolla* and *Thalassolampe*), or it may be present in the form of spicules or spines developed in the extra-capsular sarcode.

HELIOZOA.

The *Heliozoa* may be defined as *Rhizopoda, which possess a contractile vesicle, and are devoid of a central capsule. The body is naked, or is provided with skeletal structures of a variable nature, but sometimes siliceous. The pseudopodia stand out like rays, but may anastomose with one another.*

In their radiant *pseudopodia* and in the occasional presence of siliceous spicules, the *Heliozoa* are allied to the typical Radiolarians; but the absence of a central capsule and the presence of a contractile vesicle approximate them to the *Amœbea;* while the absence of "yellow cells," as also of a gelatinous outer investment to the sarcode, distinguish them further from the true Radiolarians. They must therefore be regarded as an inosculating group, related on the one hand to the *Amœbea*, and on the other to the *Radiolaria*.

Most of the *Heliozoa* are inhabitants of fresh water, and we may select as a type the common "Sun-animalcule" (*Actinophrys sol*), in which no hard structures are developed. In this animalcule (fig. 21), the body consists of a spherical mass

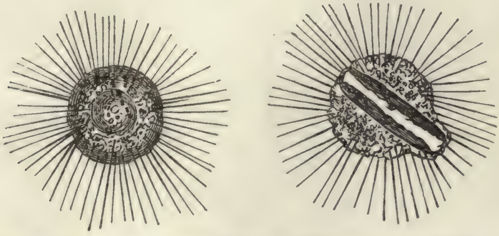

Fig. 21.—*Actinophrys sol*, showing the radiating pseudopodia. One specimen has swallowed a Diatom.

of sarcode, about 1-1300 of an inch in diameter, and usually covered with long, radiating, filamentous pseudopodia, which are much less mobile than in the case of the *Amœba*. The division of the substance of the body into ectosarc and endosarc is tolerably evident, and the latter contains numerous granules and vacuoles. The pseudopodia are derived from the ectosarc alone, the endosarc not passing into them, and they exhibit a circulation of granules along their edges, though this is not nearly so marked a feature as in the case of the *Foraminifera*. A nucleus and contractile vesicle are also present.

Actinophrys occurs in both fresh and salt water. *Actinosphærium* is in many respects like *Actinophrys*, but each of the pseudopodia is supported upon a strong albuminous spine; and the sarcode of the body is vesicular or "alveolar," while numerous nuclei exist in the central sarcode. In *Heterophrys* (fig. 22), there is a globular body, the ectosarc of which is surrounded by a kind of external investment or excretion, which appears to be of a protoplasmic nature, but takes no part in the production of the pseudopodia. The latter are long, granular, and unbranched, and amongst them are long spine-like pro-

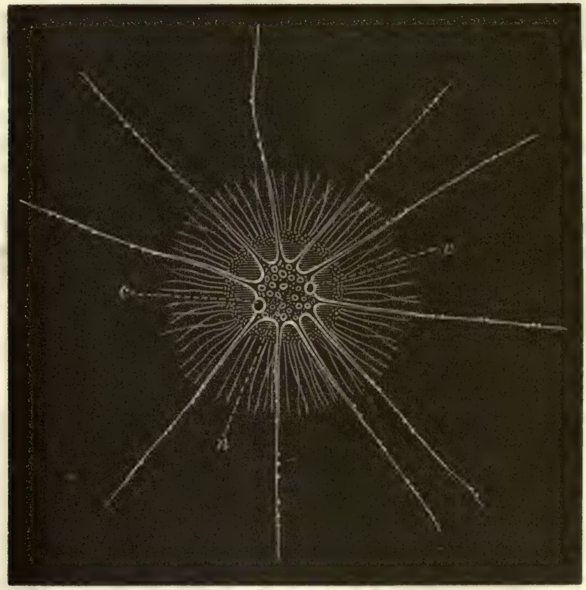

Fig. 22.—*Heterophrys spinifera*, one of the *Heliozoa*, greatly enlarged. (After Hertwig and Lesser.) *c c* Contractile vesicles.

cesses of firm sarcode, which have been regarded as of a chitinous nature. *Acanthocystis* is, like the preceding, a fresh-water form, but it possesses long radiating siliceous spines; while *Clathrulina* has the body enclosed in a regular fenestrated siliceous test, which is supported upon a siliceous peduncle.

CHAPTER V.

SPONGIDA.

ORDER V. SPONGIDA OR PORIFERA.—The true nature of sponges has long been a matter of dispute, but they are now universally referred to the animal kingdom, their precise systematic position being still a matter of dispute.*

The *Spongida* may be defined as "*sarcode-bodies destitute of a mouth, and united into a composite mass, which is traversed by canals opening on the surface, and is almost always supported by a framework of horny fibres, or of siliceous or calcareous spicula*" (Allman).

From the above definition it will be seen that a sponge is composed essentially of two elements—a soft, gelatinous, investing "flesh," and an internal supporting framework or "skeleton."

Taking an ordinary horny sponge as the type of the order, we find it to be composed of a skeleton (fig. 26) of horny reticulated fibres which interlace in every direction, and are pierced by numerous apertures, the whole surrounded externally and internally by a gelatinous glairy substance, like white-of-egg, the so-called "sponge-flesh." The horny skeleton is composed of a substance called "keratode," and is often strengthened by sand-grains, or by spicula of flint which also occur less abundantly in the sponge-flesh. These latter must not, however, be confounded with the skeleton of the typical siliceous sponges in which the keratode is wanting. Of the apertures which penetrate the substance of the sponge in every direction, some are large crateriform openings, and are termed "oscules," or "exhalant apertures;" whilst others, which occur in much greater numbers, are greatly smaller in size, and are termed "pores," or "inhalant apertures" (fig. 23). Both the oscula and pores can be closed at the will of the animal; but the oscula are permanent apertures, whereas the pores are not constant, but can be formed afresh in the outer protoplasmic covering, whenever and wherever required. The "sponge-flesh," which invests the entire skeleton, is found upon a microscopical examination to be composed of an aggregation of rounded protoplasmic bodies—the so-called "sponge-particles" or "sarcoids" (fig. 24). Some of these are provided with a single flagellum, surrounded by a membranous collar (fig. 24, B); while others are capable of emitting pseudopodia from all parts of their surface (fig. 24, C). The former of these resemble Flagellate Infusoria, and the latter are similar to *Amœbæ;* and both possess a nucleus and contractile vesicle. Others of the sarcoids, again, become undistinguishably amalgamated with one another in progress of growth, and thus give

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* High authorities consider the sponges as a division of the *Cœlenterata*, or as forming, under the name of *Porifera*, a division of the "Zoophyta" coequal with the *Cœlenterata*. This view, however, is based upon the interpretation of sponge-structure adopted by Hæckel, and the sponges will be here regarded as referable to the sub-kingdom *Protozoa*.

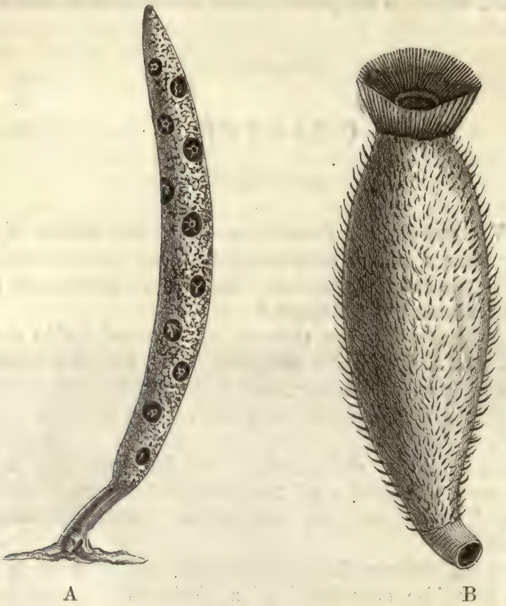

Fig. 23.—A, *Axinella polypoides,* a fibrous Sponge showing oscula and pores; B, *Sycandra ciliata*, a calcareous Sponge, showing the single terminal osculum. (After Schmidt.)

rise to a so-called "syncytium," or layer of structureless sarcode. Regarding the skeleton as something superadded, we may therefore look upon a sponge as a kind of colony, composed

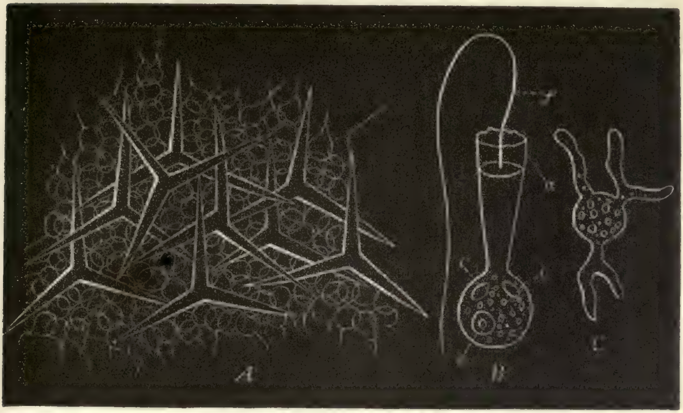

Fig. 24.—A, Portion of *Grantia*, highly magnified, showing the triradiate spicules and the sarcoids; B, A single sarcoid of *Grantia compressa*, greatly enlarged, showing the membranous collar (*a*), the flagellum (*f*), the contractile vesicles (*c c*), and the nucleus (*n*); C, A sarcoid of *Grantia compressa*, with the pseudopodia protruded and without the flagellum, greatly enlarged. (B and C are after Carter.)

of an aggregation of zoöids, of which some are amœbiform, others are like Flagellate Infusorians, and others are specially modified to form a "syncytium." The first two kinds of these zoöids are capable of procuring and assimilating food for themselves, and also of independent movements; and even fragments of the "syncytium," when detached, are capable of throwing out pseudopodia. This view of the true nature of a sponge becomes still more readily comprehensible when we consider the simplest condition in which a sponge occurs in nature (as exemplified, for instance, in certain of the *Calcispongiæ*, such as *Sycandra*, fig. 23, B); the condition, namely, in which the entire sponge consists of a colony of sarcoids, secreting a common skeleton, but provided with only a single "osculum," and a greater or less number of inhalant "pores." There are, in fact, many who hold that the more complex sponges are merely produced by the aggregation together of a number of these simpler colonies.

The above-mentioned constituents of the soft parts of an ordinary sponge are usually disposed as follows: The simpler amœbiform sarcoids make up the bulk of the colony and form the greater part of the sponge-flesh. Embedded amongst these, however, in countless numbers, are spherical groups of flagellate sarcoids, those of each group so arranged as to enclose a central space, into which water is admitted in a manner to be subsequently alluded to. The sarcoids are so disposed that the flagella of all are directed inwards into the central space, and each has its flagellum surrounded by a membranous collar, within which the lash can be retracted when not in use (fig. 24, B). Each sarcoid can nourish itself, and can discharge the indigestible portions of its food; and the surrounding water is admitted into, or shut out from, the chamber formed by the sarcoids in accordance with the temporary needs of the colony. These spherical communities of flagellate sarcoids constitute the so-called "ciliated chambers," and are to be regarded as the essential elements of the sponge. Lastly, as we have seen, portions of the sponge-flesh cannot be resolved in this way into separate sarcoids, but the latter have apparently coalesced so as to form a continuous and seemingly structureless "syncytium." This change is especially liable to take place in the layer of sarcode ("dermal membrane" or "ectoderm") which covers the exterior of a living sponge.

In a living sponge a constant circulation of water is maintained by means of an aquiferous system (fig. 25), which is constituted by the oscula and pores—already alluded to—and by a system of canals excavated in the substance of the sponge, and uniting the two sets of apertures. The water passes in by the "pores" or inhalant apertures, and is conveyed by a series of canals—the "incurrent" or "afferent" canals—to a second series of tubes—the "excurrent" or

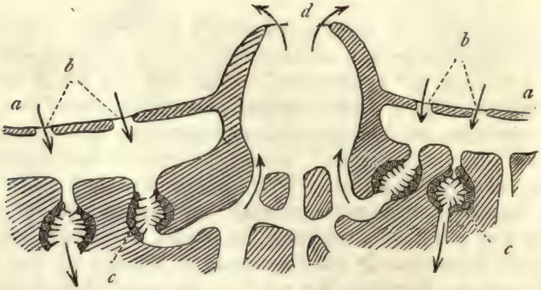

Fig. 25.—Diagrammatic section of *Spongilla* (after Huxley). *a a* Superficial layer or "dermal membrane;" *b b* Inhalant apertures or "pores;" *c c* Ciliated chambers; *d* An exhalant aperture or "osculum." The arrows indicate the direction of the currents.

"efferent" canals—by which it reaches the "oscula" and is finally expelled from the body. These processes are regularly performed, and their mechanism was long a subject of speculation. It is now known, however, that beneath the superficial layer or "dermal membrane" of the sponge there exist chambers lined with sponge-particles which are provided with vibratile filaments or flagella (fig. 25, *c c*). The pores open into these chambers, and from them proceed the incurrent canals, each being dilated at its commencement into a sac, which is also lined with flagellate sponge-particles. By the vibratile action of these cilia, currents of water are caused to set in by the pores; and as out-going currents proceed from the oscula, a constant circulation of fresh water is maintained through the entire sponge. In this way each individual sponge-particle is enabled to obtain nutriment; the process being at the same time not improbably a rudimentary form of respiration. The chambers or sacs lined with flagellate sarcoids have been shown by Mr Carter to be, as previously pointed out, the essential element in the organisation of the fresh-water and marine sponges, and to be the fundamental expression of the alimentary system.

In a few sponges (the *Myxospongiæ* of Hæckel), as in the genus *Halisarca*, there is no skeleton, and the organism consists of an aggregate of masses of sarcode, permeated by branched canals, which are everywhere inflated into chambers lined by flagellate sponge-particles or sarcoids. As a general rule, however, the soft protoplasmic aggregate which constitutes the living animal of the sponge is supported by more or less extensively-developed hard structures, which collectively form the *skeleton*. The nature of the skeleton varies greatly in different forms, and the variations are of great importance in the identification and classification of the sponges. In the so-called "horny" sponges (the *Keratosa* of Bowerbank) the skeleton (fig. 26) is composed of numerous fibres of a horny substance ("keratode") interlaced to form a matted network. In the sponges of commerce (*Spongia*) the skeleton is simply composed of these reticulated horny fibres; but in most of the "horny" sponges (such as *Halichondria*, *Spongilla*, &c.), we find in addition numerous siliceous bodies which partly strengthen the horny fibres, and are partly scattered through the sarcode. These so-called "spicules" (figs. 26 and 27) are of very varied shapes, and of microscopic dimensions, and their form is often characteristic of the particular sponge in which they occur.

The horny fibre of the skeleton of the keratose sponges is hollow; and in the sponges of commerce the axial hollow contains neither foreign bodies nor spicules. In other cases, the central tube of the horny fibres may be filled with sand-grains or with spicules, and in addition to the central core the surface of the fibre may be roughened by projecting spicules; while in some cases the fibre is almost entirely made up of simple spicules bound together by a small quantity of sarcode.

In the "so-called "calcareous" sponges (*Calcispongiæ*) such as *Grantia*, *Sycon*, &c., the skeleton is composed of numerous calcareous spicules (fig. 24, A), which are in the form of simple fusiform rods or of three-rayed (rarely four-rayed) needles, and are arranged in different ways in different species. The three-rayed spicules are the form especially characteristic of the *Calcispongiæ*, but two or all of the known forms of calcareous spicule may occur in a single sponge.

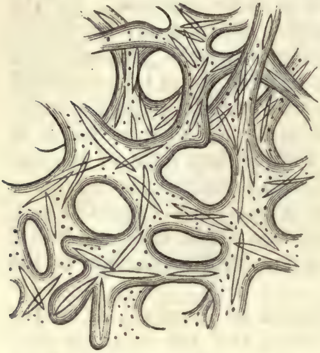

Fig. 26.—Fragment of the skeleton of a horny Sponge (after Bowerbank), greatly enlarged, showing interlacing horny fibres with spicula.

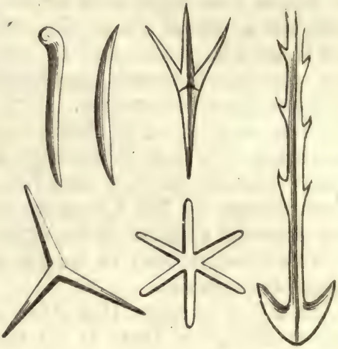

Fig. 27.—Different forms of the spicules of the horny, calcareous, and siliceous Sponges, greatly magnified.

In the so-called siliceous sponges (*Silicispongiæ*) the skeleton is composed of siliceous spicules, of various forms and variously disposed. Very commonly the spicules which primitively compose the skeleton become in process of growth fused together by a secondary siliceous deposit, so that the skeleton becomes a continuous one. In other cases, though the spicules are permanently distinct, they are so interlocked with one another as to confer practical rigidity upon the skeleton. In other cases, the spicules are united with one another by sarcode only. Independently, also, of the true skeleton-spicules, the sarcode of the body contains scattered through it numerous "flesh-spicules" of various and often very characteristic forms. Modern investigations have brought to light a great number of siliceous sponges, both living and extinct, and the structure of these is in many cases of the highest interest. Nothing further can, however, be attempted here than to briefly characterise the two principal groups of the *Silicispongiæ*—viz., the Hexactinellid and Lithistid sponges.

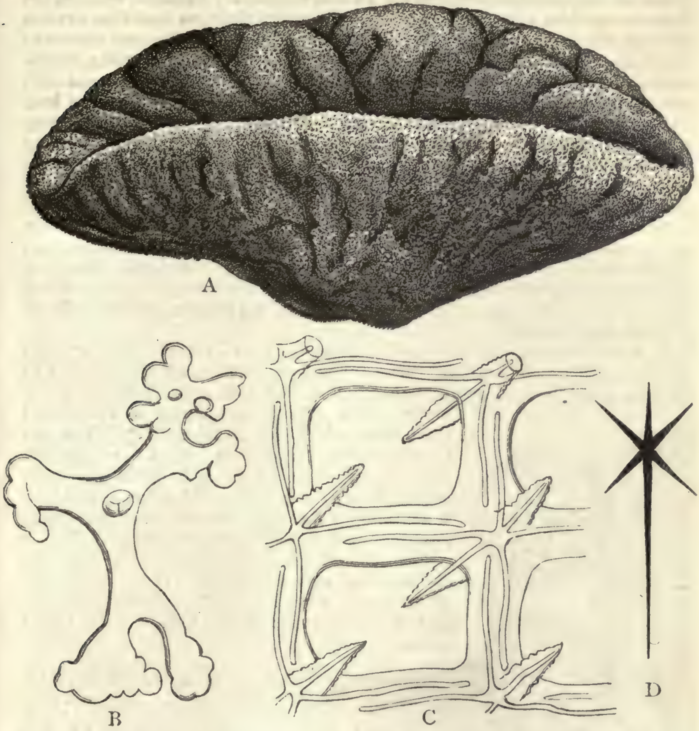

Fig. 28.—A, *Dactylocalyx pumiceus*, a Hexactinellid Sponge from the West Indies; B, A spicule of the Lithistid Sponge *Discodermia*, greatly enlarged, showing the branched ends of the spicule; C, Part of the skeleton of the Hexactinellid *Farrea occa*, greatly enlarged, showing the continuous lattice-like framework, the component spicules of which are only recognisable by their six-rayed axial canals; D, Plan of a single spicule of a Hexactinellid Sponge. (After Lütken, Sollas, and Carter.)

1. HEXACTINELLIDÆ. — In this group of the siliceous sponges the skeleton is composed of six-armed spicules, the rays of which are almost invariably at right angles to each other (fig. 28, D). In the centre of each spicule are three canals, cutting each other at right angles and forming an axial tube. The spicules become very commonly fused together by amorphous silica, so as to form a trellis-work of rectangular or polyhedral meshes, the individual spicules of which are only recognisable by the

persistence of their axial canals (fig. 28, C). The "flesh-spicules" are fundamentally six-armed, but give off secondary branches so as to form a rosette.

Among the living *Hexactinellidæ*, the Venus' Flower-basket (*Euplectella*) is one of the most familiar forms. In this exquisitely beautiful sponge, the skeleton-spicules are of large size, and the entire skeleton is at first flexible and soft, the spicules being free. Ultimately, the spicules become cemented together by a coating of vitreous silex, so as to form a ladder-like trellis-work. There is a single terminal osculum, provided with a porous lid; the sponge-body is rooted in the mud of the sea-bottom by a beard of long siliceous fibres; and the entire skeleton in the living state is completely concealed by a thick covering of brown sarcode. Another very interesting Hexactinellid sponge is the *Hyalonema* or "Glass-rope Zoophyte," long supposed to be a kind of coral. In this singular type, there is a comparatively small sponge-body, which is rooted to the mud of the sea-bottom by a long rope of delicate siliceous fibres. In addition to this skein of "anchoring-fibres," there are branched spicules, which are four-armed or five-armed in the recent forms, but are hexradiate in fossil examples. Other well-known living *Hexactinellidæ* are *Aphrocallistes*, *Farrea*, *Dactylocalyx* (fig. 28, A), &c. All the known forms are marine, and are inhabitants of deep water.

2. LITHISTIDÆ. — These are siliceous sponges in which the spicules are essentially quadriradiate, three of the four arms being so disposed as to come together at an angle of 120°, while the fourth arm lies in a different plane to the others, and forms a cylindrical shaft from which the latter spring. The extremities of the arms of the spicules are divided into processes (fig. 28, B), and by the interlocking of these, contiguous spicules are united into a continuous skeleton, the meshes of which are more or less irregular and curvilinear.

Like the Hexactinellids, the *Lithistidæ* are all marine, and inhabitants of deep water; *Discodermia*, *Corallistes*, *M'Andrewia*, *Azorica*, and *Leiodermatium* being well-known recent genera.

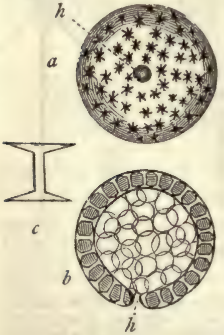

Fig. 29.—*a* Gemmule of *Spongilla; h* Hilum; *b* Diagrammatic section of the gemmule, showing the outer layer of amphidiscs and the inner mass of cells; *c* One of the amphidiscs seen in profile.

The reproduction of sponges may be effected either asexually or sexually, the following being a brief outline of the phenomena which have been observed in the common fresh-water sponge (*Spongilla*), in which the process was first accurately noticed.

In the first or asexual method of reproduction, which takes place in the winter, the deeper portions of the sponge are found to be filled with small seed-like rounded bodies, termed "gemmules" or "spores," each of which possesses a small aperture or "hilum" at one point (fig. 29, *h*). Each gemmule is composed of an outer coriaceous capsule surrounded by a layer of peculiar asteroid spicula, resembling two toothed wheels united by an axle, and termed "amphidiscs" (fig. 29, *b*, *c*). These amphidiscs are embedded in sarcode, whilst their inner surfaces rest upon the tesselated capsule already mentioned. In the interior of the capsule thus formed is a mass of protoplasmic cells, which, on the coming of spring, is extruded through the hiliform opening of the capsule into the water, and becomes developed into a young *Spongilla*.

In the second or sexual method of reproduction, certain of the sponge-particles or "sarcoids" separate themselves and become nucleolo-nucleated, thus constituting ova. At the same time other sarcoids become motionless, and their contents become molecular, and are finally converted into spermatozoa. By the rupture of these, and by the consequent contact of the different elements (fig. 30, A), embryos are produced, which are at first ciliated and move about freely, becoming eventually stationary, and developing into new individuals.

As regards the *development* of the sponges, the impregnated ovum (fig. 30, A) cleaves, by the usual process of "segmentation," into a mass of primitive cells, sometimes containing centrally a primitive and temporary cavity (fig. 30, B). These cells are divisible into two distinct groups, one of which ultimately forms the external layer (ectoderm), whilst the other forms the internal layer (endoderm). As described by Metschnikoff in the embryo of *Sycon*, these groups of cells at first form the two poles of the

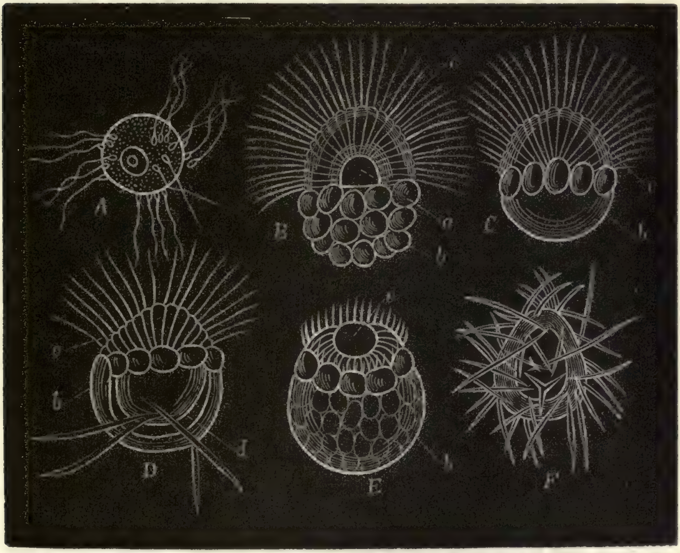

Fig. 30.—Development of *Calcispongiæ*. A, Ovum in the act of being impregnated by the spermatozoids. B, Free-swimming embryo of *Sycon*, showing the non-ciliated ectodermal cells, and the ciliated endodermal cells, the latter enclosing a temporary "segmentation-cavity" (*a*). C, The embryo further advanced, with the ciliated half of the body reduced in size. D, The embryo at a later stage, showing the primitive spicules, and the commencing body-cavity (*d*). E, Unattached larva, without the skeleton; the ciliated endoderm has now been withdrawn within the non-ciliated ectoderm, and the primitive opening into the body-cavity (*e*) has been formed by invagination. F, Young *Sycon*, six days old, showing the skeleton. *b* Non-ciliated ectodermal cells; *c* Ciliated endodermal cells. (A is after Hæckel; B, C, D, E, and F are after Metschnikoff.)

larva, the cells of the endoderm being ciliated (fig. 30, B, *c*), and enabling the organism to swim actively through the water, whilst the cells of the ectoderm are non-ciliated (fig. 30, B, *b*). In the process of growth, the ciliated endodermal cells become gradually retracted into the interior of the larva (fig. 30, C and D), till the body becomes completely invaginated upon itself. In this condition (fig. 30, E) it forms what Hæckel terms a "gastrula," and consists of two layers of cells, an outer and an inner, enclosing a central cavity, which communicates with the outer water by a single primitive opening. This aperture is formed by the invagination of the body, and not by rupture of the walls of the central cavity. The skeleton is formed in the ectodermal layer, and the primitive opening into the body-cavity becomes finally effaced. In its further development, the young sponge, now consisting of two cellular layers surrounding a closed central cavity (fig. 30, F), fixes itself by one extremity to some foreign object; a primitive "osculum" is developed at the free extremity of the larva; and the walls become perforated with numerous small apertures, which ultimately become the inhalant openings or "pores" of the adult. It should be added that the account of the development of the *Calcispongiæ* given by Hæckel differs in some points very materially from the above.

It should be added, further, that according to the researches of Mr Saville Kent, the so-called "ciliated embryo" of the sponges is not composed of "cells," in the ordinary acceptation of this term, but is "a spherical or ovate aggregation of typical collar-bearing Monads or spongozoa, connected laterally and by their bases with one another, and with their anterior flagellate collar-bearing extremity directed outwards."

DISTRIBUTION OF SPONGES IN SPACE.—Sponges are almost exclusively marine, the *Spongillæ* alone being inhabitants of fresh water; and they are of almost universal occurrence. The sponges of commerce are mostly obtained from the Grecian Archipelago and the Bahama Islands. The common marine sponges are mostly found attached to some solid object between tide-marks or in deep water. One genus (*Cliona*) inhabits branching cavities in shells, which the sponge excavates for itself, apparently by means of its siliceous spicula; and fossil shells mined by a boring-sponge, allied to the recent *Clionæ*, are found from the Silurian rocks upwards. The siliceous sponges appear to be exclusively inhabitants of the deeper parts of the ocean, and our knowledge of these beautiful forms has been enormously increased during late years by the researches into the fauna of the deep sea, which have been carried out by Sir Wyville Thomson, Carpenter, Sars, and other well-known observers. Much also has been added to our knowledge of the *Calcispongiæ* by the elaborate investigations of Hæckel, Oscar Schmidt, Metschnikoff, and others. The calcareous sponges are all marine, and all inhabitants of shallow water, and the living forms are all of small size.

DISTRIBUTION OF SPONGES IN TIME.—Remains of sponges are known to occur in formations belonging to the Palæozoic, Mesozoic, and Kainozoic epochs. The keratose or horny sponges are obviously incapable of leaving any evidence of their existence, otherwise than by the preservation of the spicula with which the skeleton is sometimes furnished; and such are occasionally found, though they are of rare occurrence. The calcareous sponges are found from the Silurian rocks upwards, though great obscurity still rests upon the true nature and affinities of many of the fossils which have been referred to this group.

The siliceous sponges are now known to possess a very high antiquity, both the sections of the *Hexactinellidæ* and *Lithistidæ* being developed as early as the Silurian period. Of the fossil *Hexactinellidæ*, the best-known group is that of the *Ventriculitidæ*, comprising a large number of beautiful Secondary sponges. Of the fossil Lithistids, the best-known genus is the widely distributed *Siphonia* of the Cretaceous period.

AFFINITIES AND SYSTEMATIC POSITION OF THE SPONGES.—Great doubts still exist as to the real relations and zoological place of the sponges; and though placed here with the *Rhizopoda*, there are many considerations which render this collocation objectionable. The opinions of naturalists in this matter are still unsettled, and the whole subject is a very complex one, so that it will be sufficient to simply allude to one or two of the more important points affecting this question. We have seen that each sponge may be regarded as an aggregate of protoplasmic masses (sarcoids), each of which is morphologically a single "cell." This fact in itself, as pointed out by Hæckel, is an important one, for the typical Rhizopod, such as *Amœba*, is to be looked upon as morphologically a single cell leading an independent life, and singly discharging all the functions of vitality. Upon this ground, as well as upon weighty developmental grounds, Hæckel would remove the sponges altogether from the *Protozoa*, and would place them among the *Cœlenterata*. On the other hand, the individual "sarcoid" of a sponge, if non-flagellate, presents a resemblance to an *Amœba*, which is far too striking to be overlooked; whilst the flagellate sarcoids present an equally conspicuous similarity to the flagellate Infusoria. Indeed it is very difficult to see upon what classificatory principle those sponges (such as *Halisarca*) which have no skeleton can be separated from such compound flagellate Infusoria as *Phalansterium*, except that the latter is without the canal-system which traverses the protoplasm of the former. There are also many points of affinity between the sponges and the *Radiolaria*. These considerations appear to be sufficient, in the meanwhile, and in a work of this nature, to justify the retention of the *Spon-*

gida in the sub-kingdom *Protozoa*, in which case they find their most natural position in or close to the *Rhizopoda*. It is to be remembered, however, that they differ from the other *Protozoa* and agree with the *Cœlenterata* in the fact that the adult is multicellular; that the ovum breaks up on fecundation into a mass of primitive embryonic cells; and that the larva passes through a stage ("gastrula" stage) in which it is composed of an outer and inner cellular layer, enclosing a central cavity, which communicates with the outer world by a single opening. It should be borne in mind, on the other hand, that there are some undoubted *Protozoa* (*e.g.*, some of the Radiolarians) which have strong claims to be regarded as multicellular organisms.

CHAPTER VI.

INFUSORIA.

THE *Infusoria* of many writers comprise many of the lowest forms of plants—such as the *Diatoms*—together with the *Rotifera*, a class of minute animals now known to belong to the *Annulosa*. By modern writers, however, the term *Infusoria* is used strictly to designate those *Protozoa* which possess a mouth and rudimentary digestive cavity. They are, for this reason, often called collectively the "stomatode" *Protozoa*, in contradistinction to the remaining members of the sub-kingdom, which are all "astomatous." The so-called "suctorial" *Infusoria* (*Acinetæ*), however, appear to have no definite oral aperture; and the same is the case with the parasitic *Opalina*, though there is great doubt as to the propriety of placing this in the *Infusoria* at all. The name *Infusoria* itself is derived from the fact that the members of the class are often developed in organic infusions.

The *Infusoria* or *Stomatode Protozoa* may be defined as *Protozoa which are mostly provided with a mouth and rudimentary digestive cavity, which do not possess the power of emitting pseudopodia, but which are furnished with vibratile cilia, or with contractile filaments. They are mostly microscopic in size, the sarcode is differentiated into an ectosarc and an endosarc, and a nucleus and contractile vesicle are present.*

Most modern writers regard the *Infusoria* as strictly speaking "unicellular" animals, each of the simple individuals corresponding morphologically to a single cell. Upon this view—

which is by no means free from difficulties—the "nucleus" of the Infusorian animalcules really corresponds with the structure known by the same name in an ordinary animal or vegetable cell.

The *Infusoria* may be divided into three orders — viz., *Suctoria*, *Ciliata*, and *Flagellata*—of which the second comprises the majority of the members of the class, and alone requires much consideration.

I. Order Ciliata.—This order comprises those *Infusoria in which the outer layer of the body is more or less abundantly furnished with vibratile cilia, which serve either for locomotion or for the procuring of food.* Besides *cilia*, properly so called, some of the ciliated *Infusoria* are provided with *styles* or jointed bristles, which are movable, and subserve locomotion; whilst others have little hooks or *uncini*, with which they can attach themselves to foreign bodies. As types of the order, *Paramœcium* and *Vorticella* may be selected, the former being free, whilst the latter is permanently fixed in its adult condition.

Paramœcium (figs. 31 and 32) is a slipper-shaped animalcule, composed externally of a structureless transparent pellicle — the "cuticle" — which is lined by a layer of firm and consistent sarcode, which is termed the "cortical layer," or the "parenchyma of the body," this in turn passing into a central mass of softer and more diffluent sarcode, known as the "chyme-mass," or "endoplasm." The cuticle is merely the structureless hardened external lamina of the "cortical layer," and it may in some cases form a regular protective sheath (*Vaginicola*), a horny shell (*Codonella*), or even a reticulated siliceous envelope (as in *Dictyocysta*). Beneath

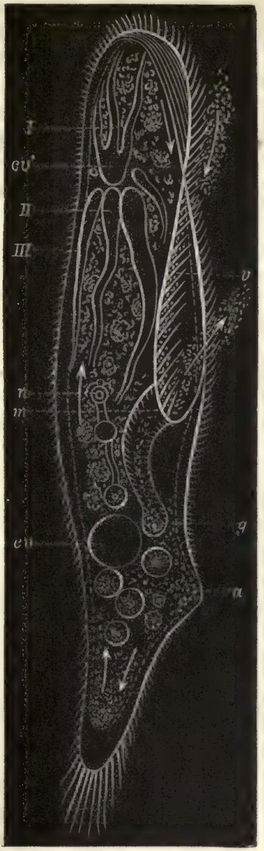

Fig. 31.—*Paramœcium*, viewed dorsally, and greatly magnified. *m* Mouth; *m* to *g* Gullet; *a* Anus; *cv'* and *cv* The contractile vesicles; I, II, III, Canals proceeding from the anterior contractile vesicle; *n* Nucleus; *v* Large cilia bounding the depression ("vestibule") leading to the mouth. The arrows indicate the course in which the particles of food circulate in the semi-fluid protoplasm of the interior of the body. (After James-Clark.)

the "cuticle" is the layer from which the cilia are given off, and below that, again, is a finely striated or fibrillated contractile layer ("myophane layer" of Hæckel), which corresponds physiologically to the muscles of higher animals. In some Infusorians there is a still more internal lamina of the "cortical layer," which is charged with the singular little organs known as "trichocysts." These are vesicular microscopic bodies, capable of emitting thread-like filaments, in many respects closely resembling the "thread-cells" of the *Cœlenterata*.

The "cuticle" in *Paramœcium* is covered with vibratile cilia (figs. 31 and 32), and is perforated by the aperture of the mouth.

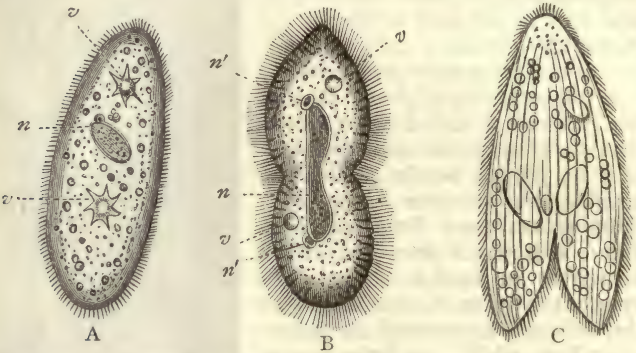

Fig. 32.—A, *Paramœcium*, showing the nucleus (*n*) and two contractile vesicles (*v*). B, *Paramœcium bursaria* (after Stein) dividing transversely: *n* Nucleus; *n'* Nucleolus; *v* Contractile vesicle. C, *Paramœcium aurelia* (after Ehrenberg), dividing longitudinally.

The mouth leads into a funnel-shaped gullet, which is not continued into a distinct digestive sac, but loses itself in the soft central protoplasm. On the line of boundary between the cortical layer and the diffluent central sarcode are placed the "nucleus" and the "contractile vesicle" (or vesicles). The "nucleus" is an oval body (in some forms band-shaped or rod-like), consisting of an outer membrane enclosing granular contents, and often having a smaller spherical particle applied to its exterior or immersed in its substance. This latter is the so-called "nucleolus," which must be carefully distinguished from the nucleolus of a cell, which occurs in the *interior* of the nucleus. The contractile vesicles are clear spaces, which contract and dilate at intervals, and occasionally exhibit radiating canals passing into the surrounding sarcode. Ordinarily one contractile vesicle is present, or at most two, but in some cases there may be several. It has also been maintained that the contractile vesicles communicate with the exterior of the body, but proofs are wanting on this point. Whether this should ultimately be established or not, there can be little doubt but that the vesicles are a rudimentary form of vascular apparatus. Others, however, hold, with some probability, that the contractile vesicles are to be regarded as excretory in function, and that they correspond more with the water-vascular system of the *Scolecida* than with the true blood-vascular system of higher animals. Certain other spaces termed "vacuoles" are generally visible in addition to the contractile vesicles. These, however, are probably merely collections of water surrounding the particles of ingested food, and performing with them a circulation in the abdominal cavity, something like the circulation of granules which is seen in certain vegetable cells. It was the appearance of these "vacuoles"—which are certainly not permanent organs of any kind—which induced Ehrenberg to term the *Infusoria* the "Polygastrica," upon the belief that the vacuoles were so many stomachs.

Paramœcium obtains its food by means of the currents of water which are set up by the constantly vibrating cilia. The nutritive particles thus brought to the mouth pass into the central abdominal cavity, along with the contents of which they undergo the circulation above spoken of. Indigestible and fæcal particles appear to be expelled by a distinct anal aperture, which is situated near the mouth.

Reproduction in *Paramœcium* may be effected non-sexually, by fission, the body dividing transversely into two halves, and the process of cleavage commencing first with the division of the nucleus (fig. 32, B). Longitudinal fission is also stated to occur (fig. 32, C); but it is questionable whether the appearances which have led to this statement may not really be due to the coalescence and temporary conjugation of two individuals. Most authorities further believe that *Paramœcium* has the power of true sexual reproduction, the "nucleus" playing the part of an *ovary* in the process, and the "nucleolus" acting as a *testis*. In this process, as described by Balbiani, two *Paramœcia* come together, and adhere closely to one another by their ventral surfaces. The "nucleus" increases in size, and a number of ovules are formed in its interior. In like manner, the "nucleolus" of each also enlarges, and develops in its interior a number of fusiform or rod-like bodies, which are believed to be spermatozoa. The nucleolus of each then passes into the body of the other, the act of transference being effected through the mouth. Contact of the two reproductive elements then takes place, and the fecundated ovules after their liberation from the body of the parent are developed into adult *Paramœcia.*

Other observers, however, are disposed to believe that this "conjugation" of two *Paramœcia* is not a genuine sexual process, that the "nucleolus" is not a true testis, and that the rounded bodies into which the "nucleus" breaks up can be developed into new individuals directly and without contact with a second reproductive element.

Vorticella (fig. 33, C) is a beautiful flower-like Infusorian which is commonly found in fresh water, adhering to the stems of aquatic plants. It consists of a bell-shaped body or "calyx," supported upon the extremity of a slender contractile stem or "pedicle." The other extremity of the pedicle is fixed to some foreign body, and its power of contraction is due to the presence in its interior of a spiral contractile fibre, which is sometimes called the "stem-muscle." The edge of the bell or calyx is surrounded by a projecting rim or border, called the "peristome," within which is a circular surface, the "disc," forming the upper extremity of the so-called "rotatory organ." The disc is surrounded by a fringe of vibratile cilia, forming a spiral line which is prolonged into the commencement of the digestive canal. Near the edge of the disc is situated the mouth, which conducts by its entrance or "vestibulum" into a fusiform canal or "pharynx," which terminates abruptly in the abdominal cavity. The particles of food are taken in at the mouth, descend through the short alimentary canal, and enter the abdominal cavity, where they are subjected to the general rotation of the "chyme-mass," being finally excreted by an anal aperture which is situated near the mouth and within the vestibule. As in *Paramœcium*, the body in *Vorticella* is composed of an outer "cuticle," a central "chyme-mass," and an intermediate "cortical layer," which contains a contractile vesicle and a band-like nucleus.

Reproduction in *Vorticella* may take place by fission, or by gemmation, or by a process of encystation and endogenous division. In the first of these modes the calyx becomes indented in a longitudinal direction—viz., from the pedicle to the disc; and the groove thus formed becomes gradually deeper until the calyx is finally divided into two halves supported upon the same pedicle. On one of these cups a "posterior" circlet of cilia is then formed in addition to the "anterior" circlet already existing (*i. e.*, a fringe of cilia is developed round that end of the calyx which is nearest the attachment of the pedicle and furthest from the disc). The cup (fig. 33, D), thus furnished with a circlet of cilia at both extremities, is then detached, and swims about freely. Finally, the *anterior* circlet of cilia disappears, and this end of the calyx puts forth a pedicle and becomes attached to some foreign object. A new mouth is now formed within what was before the *posterior* circlet of cilia; so that the position and function of the two extremities of the calyx are thus reversed.

In the second mode of reproduction — namely, that by gemmation — exactly the same phenomena take place, with this single difference, that in this case the new individual is not produced by a splitting into two of the adult calyx, but by means of a bud thrown out from near its proximal extremity. This bud is composed of a prolongation of the cuticular and cortical layers of the adult with a cæcal diverticulum of the abdominal cavity or chyme-mass. It soon develops a posterior circlet of cilia, the connection with the parent is rapidly constricted until complete separation is effected, and then the process differs in no respect from that described as occurring in the fissiparous method of reproduction. According to Stein and Greeff, however, these so-called "buds" are really small calyces, produced by fission of one *Vorticella* and then attaching themselves to the outside of the calyx of another individual.

In the third mode of reproduction the *Vorticella* encysts itself in a capsule, the cilia and pedicle disappear, and the nucleus breaks up into a number of rounded germs, which are ultimately liberated by the rupture of the cyst, and after a short locomotive stage, develop themselves into fresh *Vorticellæ*. How far this process may be truly sexual is not known, and no form of unequivocal sexual reproduction has hitherto been shown to occur in the case of *Vorticella*.

Epistylis is a not uncommon form of fixed Infusorian which is nearly allied to *Vorticella*, and differs chiefly in the fact that the pedicle is much branched, and rigid and not contractile. It usually occurs in the form of a greyish-white nap on the stems of water-plants, or on the head of the common water-beetle, the *Dytiscus marginalis*. It consists of a plant-like branching and re-branching frond, the stems of which are quite transparent and faintly striated, but are not contractile, though capable of movement from side to side. Each branch of the entire colony terminates in an oval calyx, articulated to the stem by a distinct joint, upon which it can move from side to side. The sarcode-body enclosed within the cortical layer is of a light-brown colour, and full of minute granules, with larger food-vacuoles and a well-marked contractile vesicle, which contracts and dilates two or three times a minute. The animal can retract itself entirely within its cup, and can at will exsert a ciliated disc.

Carchesium is another form which is like *Epistylis* in consisting of a number of calyces supported upon a branched pedicle, but differs from *Epistylis* and agrees with *Vorticella* in the fact that the pedicle is contractile.

Stentor, or the trumpet-animalcule (fig. 33, A), is another common Infusorian which is closely related to *Vorticella*. It consists of a trumpet-shaped calyx, devoid of a pedicle, but possessing the power of attaching and detaching itself at will. When detached it swims by means of the anterior circlet of cilia, just as the calyx of *Vorticella* will if broken from its stalk. In *Vaginicola* (fig. 33, B) the essential structure is much the same as in *Vorticella*, but the body is protected by a membranous or horny case ("carapace" or "lorica"), which is formed by a hardening of the cuticle, and within which the animal can retire.

II. ORDER SUCTORIA.—This order includes a series of *Infusoria* of a very anomalous nature. In *Acineta* or in *Podophrya* (fig. 34, A), which may be taken as types, the body is provided with a number of radiating filamentous tubes, which are furnished at their extremities with suctorial discs, and are capable both of exsertion and retraction. These retractile tubes both seize the prey and serve as vehicles for the ingestion of food: hence the term "polystome," or many-mouthed, has been proposed for the order by Professor Greene. A nucleus and one or more contractile processes are present, but they possess no cilia in their adult condition, and the body is fixed to some foreign object by a stalk-like extension of the cortical layer.

III. ORDER FLAGELLATA.—This order comprises those *In-*

fusoria which, like *Peridinium*, find their means of locomotion in long, flexible, lash-like filaments, termed "flagella;" cilia occasionally being present as well. In some, as in *Peranema* and in the Monads (fig. 34, B), there is only a single one of these appendages; in others, as in *Anisonema*, there are two flagella; whilst in *Heteromastix* (fig. 34, G) and *Pleuronema* we have forms apparently transitional between the *Ciliata* and the *Flagellata*, since both cilia and flagella are present in these genera. In all their other essential characters the flagellate *Infusoria* do not differ from the more typical members of the class, with which they agree in possessing a cuticle, a firm cortical layer, and a soft granular central parenchyma, whilst they possess a nucleus and one or more contractile vesicles. They have, however, the peculiarity that, in many cases at any rate, the base of the flagellum is surrounded by a cup-like or cylindrical membranous collar, which can be retracted at will. Many also (as *Euglena*, *Astasia*, *Heteromastix*) possess the singular brightly-coloured mass of pigment which is known as the "eye-spot," and which may possibly be a species of sense-organ (fig. 34). In one singular form (*Phalansterium intestinale*), the organism consists of numerous zoöids, each with a single flagellum and projecting membranous collar, enveloped basally in slimy sarcode, so as to form a cylindrical colony.

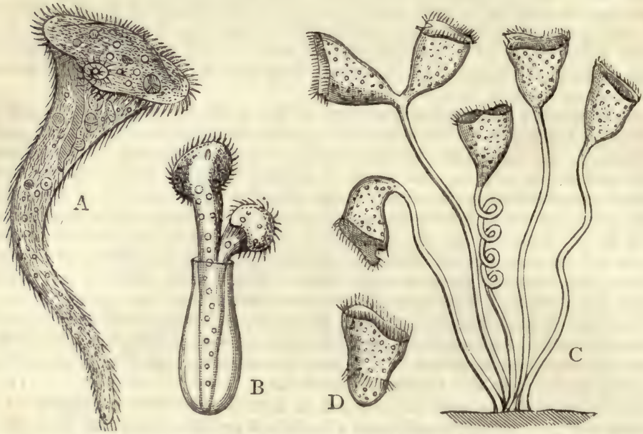

Fig. 33.—A, *Stentor Mülleri*; B, *Vaginicola crystallina*; C, Group of *Vorticellæ*; D, Detached bud of *Vorticella*, showing the posterior circlet of cilia.

Another remarkable animalcule now usually referred to this group is *Noctiluca*, which occurs abundantly in most oceans, and to which much of the phosphoresence of the sea is due.* It is of large size and spherical in form, with an indentation or "hilum" at one side, where the mouth is situated, and beside which is fixed a single long flagellum. The body consists of a central vacuolated mass of protoplasm, surrounded by a superficial layer, and in turn invested by a thin cuticle. The superficial layer is connected with the central protoplasmic parenchyma by numerous radiating, branched, and anastomosing filaments of sarcode. The luminosity appears to reside in nucleated cellular bodies in the outer layer of the central protoplasm—that is to say, in the peripheral layer of sarcode immediately below the cuticle.

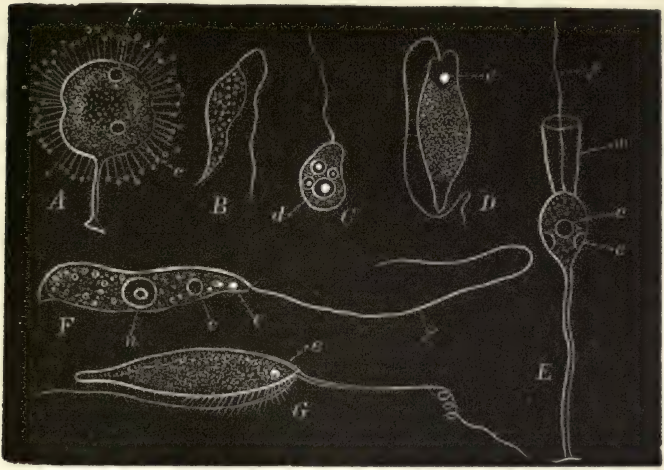

Fig. 34.—Suctorial and Flagellate Infusoria. A, *Podophrya*; B, *Cercomonas truncata*; C, *Monas neglecta*; D, *Euglena sanguinea*; E, *Ccdosiga pulcherrima*; F, *Astasia trichophora*; G, *Heteromastix proteiformis*. *f* Flagellum; *m* Collar at the base of the flagellum; *c* Contractile vesicle; *n* Nucleus; *e* Eye-spot. (After Pritchard, Ehrenberg, and James-Clark.)

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* The *diffused* luminosity of the sea is mainly due to the *Noctiluca miliaris*; but its partial luminosity is due to various phosphorescent animals, amongst which are the *Physalia utriculus* (the Portuguese man-of-war), *Medusæ*, *Tunicata*, *Annelides*, &c. The cause of phosphorescence is variously stated, it being supposed very generally to be the result of a process of slow combustion analogous to that which takes place in phosphorus when exposed to the atmosphere. Upon the whole, however, it appears that the phenomenon is a vital process, consisting essentially in the conversion of nervous force (or vital energy) into light; just as the same force can be converted by certain fishes into electricity. This transformation appears generally to require a special apparatus for its production.

DISTRIBUTION OF THE INFUSORIA IN SPACE AND IN TIME.—The *Infusoria* have at the present day an almost universal distribution, being found in all collections of fresh and salt water, where decaying organic matter is present, and where the other conditions of life are favourable. A few are parasites in the interior of other animals (*Opalina*), but the true affinities of these are doubtful. Owing to the fact of their generally wanting any hard structures which could have been preserved in a fossil condition, no true *Infusoria** can be said with certainty to have existed in former periods of the earth's history, though they have doubtless abounded in past time as now. The only possible exceptions to this statement are certain microscopic bodies which occur in the Chalk-flints, and which Ehrenberg considered to be the protective carapaces of *Peridinium* and allied forms of flagellate Infusoria.

LITERATURE.

[In the subjoined list, as well as in those which will be subsequently given, it is hardly necessary to say that nothing further will be attempted than to furnish the student with a brief and limited *selection* from the numerous works and memoirs relating to the animals belonging to each subkingdom. It has also not appeared needful to cite the names of well-known manuals and text-books of zoological science, save where these contain special information.]

GENERAL WORKS.

1. "Die Klassen und Ordnungen des Thier-Reichs," vol. i. Amorphozoa. Bronn.
2. "Manual of the Protozoa." Greene.
3. "Micrographic Dictionary." Griffiths and Henfrey.
4. "The Microscope and its Revelations." 5th ed., 1875. Carpenter.
5. "Life-Histories of Animals." Packard.
6. "Recent Researches among some of the more Simple Sarcode Organisms." 'Journ. Linn. Soc.,' vol. xiii., 1877. Allman.

GREGARINIDA.

7. "Icones Histiologicæ," vol. i. p. 7. Kölliker.
8. "Ueber die Natur der Gregarinen." 'Müller's Archiv für Anatomie,' 1848. Stein.
9. "On a new Species of Gregarina to be called *Gregarina gigantea*." 'Quart. Journ. Microscop. Science,' vol. x., 1870. Van Beneden.

MONERA.

10. "Monographie der Moneren." 'Jenaische Zeitschrift für Medecin und Naturwiss.,' vol. iv., 1868. (Translated in 'Quart. Journ. Microscop. Science,' 1869.) Hæckel.
11. "Beiträge zur Kenntniss der Moneren." Schultze's 'Archiv für Mikroscopische Anat.,' vol. i., 1865. Cienkowski.

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* "Fossil Infusoria" are often spoken of as forming more or less extensive deposits in the earth's crust, but the organisms so named are really *Diatoms* and *Polycystina*.

AMŒBEA.

12. "Études sur les Infusoires et les Rhizopodes," vol. i. p. 413. Claparède and Lachmann.
13. "Ueber die Einzelligkeit der Amœben." 'Zeitschrift für Wiss. Zoologie,' 1855. Auerbach.
14. "On some Fresh-water Rhizopods." 'Quart. Journ. Microscop. Science,' 1869-71. Archer.
15. "Fresh-water Rhizopods." 'Annals of Nat. Hist.,' ser. 3, vol. xiii., 1864. Carter.
16. "Amœba villosa," &c. 'Annals of Nat. Hist.,' ser. 3, vol. xi., 1863. Wallich.
17. "Ueber Rhizopoden und denselben nahestehende Organismen." 'Archiv für Mikr. Anat.,' vol. x., suppl. 1874. Hertwig and Lesser.
18. "Rhizopoden-Studien." 'Archiv für Mikr. Anat.,' vol. xi., 1875. F. Eilhard Schultze.

FORAMINIFERA.

19. "Introduction to the Study of the Foraminifera" ('Ray Society'), 1862. Carpenter.
20. "Ueber den Organismus der Polythalamien." 1854. Schultze.
21. "On the Recent Foraminifera of Great Britain" ('Ray Society'), 1858. Williamson.
22. "Researches on the Foraminifera." 'Phil. Trans.,' 1856-57. Carpenter.
23. "Handbuch der Palæontologie," vol. i. pp. 61-114, 1876. Zittel.
24. "Carboniferous and Permian Foraminifera" (with a general Introduction). 'Monographs of the Palæontographical Society,' 1876. H. B. Brady.
25. "Mikrogeologie." Ehrenberg.
26. "Foraminifères Fossiles du Bassin Tertiaire de Vienne." D'Orbigny.
27. "Ueber den Kern der Foraminiferen.' 'Archiv für Mikr. Anat.,' 1876. F. Eilhard Schultze.
28. "Reticularian Rhizopoda of the Challenger Expedition." 'Quart. Journ. Micr. Science,' vol. xix., 1879. H. B. Brady.

RADIOLARIA.

29. "Ueber die Thalassicollen, Polycystinen, und Acanthometren des Mittelmeeres." 'Abhandl. d. K. Akad. Berlin,' 1858 (also in 'Quart. Journ. Microscop. Science,' 1859). J. Müller.
30. "Die Radiolarien," 1862. Hæckel.
31. "Mikrogeologie." Ehrenberg.
32. "Fortsetzung der Mikrogeologischen Studien," &c. 'Abhandl. d. K. Akad. Berlin,' 1875. Ehrenberg.
33. "On Thalassicolla." 'Annals of Nat. Hist.,' 1851. Huxley.
34. "Actinophrys sol." 'Quart. Journ. Microscop. Science,' 1853. Kölliker.
35. "Heliozoa." 'Quart. Journ. Microscop. Science,' 1876, 1877. Archer.
36. "Recent Researches on the Radiolarians." 'Journ. Linn. Soc.,' vol. xiv., 1878. St George Mivart.
37. "Ueber Radiolarien, &c., des süssen Wassers." 'Archiv für Mikr. Anat.,' 1869. Greeff.

SPONGIDA.

38. "Observations and Experiments on the Structure and Functions of the Sponges." 'Edin. Phil. Journ.,' vols. xiii., xiv.; and Edin. New Phil. Journ.,' vol. i., 1825-27. Grant.

39. "Anatomy and Physiology of the Spongiadæ." 'Phil. Trans.,' 1859. Bowerbank.
40. "British Spongiadæ" ('Ray Society'). Bowerbank.
41. "History of British Sponges and Lithophytes." Johnston. 1842.
42. "Die Spongien des Adriatischen Meeres," 1862-66. Oscar Schmidt.
43. "Grundzüge einer Spongien-Fauna des Atlantischen Gebietes," 1870. Oscar Schmidt.
44. "Die Kalk-Schwämme." Hæckel. 1872.
45. "Anatomy and Classification of Sponges." 'Annals of Nat. Hist.,' 1875. Carter.
46. "Vitreous Sponges," 'Annals Nat. Hist.,' 1868. Wyville Thomson.
47. "Classification of Sponges." 'Proc. Zool. Soc.,' 1867. Gray.
48. "Development of the Marine Sponges." 'Annals Nat. Hist.,' 1874. Carter.
49. "Development of the Calcispongiæ." 'Annals Nat. Hist.,' 1875. (Translation.) Metschnikoff.
50. "The Spongiæ ciliatæ as Infusoria flagellata." 'Annals Nat. Hist.,' 1868. James-Clark.
51. "The Depths of the Sea," 1873. Wyville Thomson.
52. "On Holtenia." 'Phil. Trans.,' 1870. Wyville Thomson.
53. "On Cliona." 'Annals. Nat. Hist.,' 1849. Albany Hancock.
54. "Ventriculitidæ of the Chalk." 'Annals Nat. Hist.,' 1847, 1848. Toulmin Smith.
55. "Untersuchungen über Hexactinelliden." 'Zeitschr. für Wiss. Zool.,' vol. xxv., 1877. W. Marshall.
56. "Handbuch der Palæontologie," vol. i., part 2, 1879. Zittel.
57. "Beiträge zur Systematik fossiler Spongien." 'Neues Jahrb. für Min. Geol. und Paleont.,' 1877, 1878. Zittel.
58. "On Hæckel's Group of the 'Physemaria,' and on the Affinities of the Sponges." 'Ann. Nat. Hist.,' ser. 5, vol. i., 1878. Saville Kent.
59. "On the genus Haliphysema." 'Ann. Nat. Hist.,' ser. 5, vol. i., 1878. A. M. Norman.

INFUSORIA.

60. "Die Infusionsthierchen als volkommene Organismen," 1838. Ehrenberg.
61. "Infusoires," 1841. Dujardin.
62. "Der Organismus der Infusionsthiere," 1867. Stein.
63. "Études sur les Infusoires et les Rhizopodes." 'Mem. de l'Institut National Genevois,' 1858-61. Lachmann and Claparède.
64. "Recherches sur les organes générateurs et la reproduction des Infusoires." 'Comptes Rendus,' 1858. Balbiani.
65. "Untersuchungen über den Bau und die Naturgeschichte der Vorticellen." 'Archiv für Naturg.,' 1870. Greeff.
66. "Zur Morphologie der Infusorien." 'Jenaische Zeitschrift,' vol. vii., 1873. Hæckel.
67. "Ueber einige neue pelagische Infusorien." 'Jenaische Zeitschrift,' vol. vii., 1873. Hæckel.
68. "History of Infusoria." Pritchard.
69. "Recent Progress in our Knowledge of the Ciliate Infusoria." 'Proc. Linn. Soc.,' 1875. Allman.
70. "Flagellate Infusoria." 'Annals Nat. Hist.,' 1868. James-Clark.
71. "Beiträge zur Kenntniss der Monaden." 'Archiv für Mikr. Anat.,' 1865. Cienkowski.
72. "Researches on the Life-History of the Monads." 'Monthly Micr. Journ.,' vols. x.-xiii., 1873-75. Dallinger and Drysdale.

CŒLENTERATA.

CHAPTER VII.

THE SUB-KINGDOM CŒLENTERATA.

1. CHARACTERS OF THE SUB-KINGDOM. 2. DIVISIONS. 3. GENERAL CHARACTERS OF THE HYDROZOA. 4. EXPLANATION OF TECHNICAL TERMS.

THE Sub-kingdom *Cœlenterata* (Frey and Leuckhart) may be considered as a modern representative of the *Radiata* of Cuvier. From the *Radiata*, however, the *Echinodermata* and *Rotifera* have been removed, the entire sub-kingdom of the *Protozoa* has been taken away, and the *Polyzoa* have been relegated to their proper place amongst the *Mollusca*. Deducting these groups from the old *Radiata*, the residue, comprising most of the animals commonly known as Polypes or Zoophytes, remains to constitute the modern *Cœlenterata.*

The *Cœlenterata* may be defined as *animals whose alimentary canal communicates freely with the general cavity of the body* ("*somatic cavity*"). *The substance of the body is made up of two fundamental membranes—an outer layer, called the "ectoderm," and an inner layer, or "endoderm." There are no distinct neural and hæmal regions, and in the great majority of the members of the sub-kingdom there are no traces of a nervous system. Peculiar urticating organs, or "thread-cells," are usually present; and, generally speaking, a radiate condition of the organs is perceptible, especially in the tentacles with which most are provided. In all the Cœlenterata distinct reproductive organs have been shown to exist.*

The leading feature which distinguishes the *Cœlenterata*, and the one from which the name of the sub-kingdom is derived, is the peculiar structure of the digestive system. In the *Protozoa*, as we have seen, a mouth is only present in the higher forms, and in no case is there any definite internal cavity bounded by the walls of the body to which the name of "body-cavity" or "somatic cavity" could be properly applied (unless it be allowed that such really exists in the sponges). In animals higher than the *Cœlenterata*, on the other hand, there is not only generally a permanent mouth, but the walls of the body usually enclose a permanent chamber or "body-cavity." Further, in most cases, the mouth conducts into an alimentary canal, which is always distinct from the body-cavity, never opening into it, but usually passing through it to open on the surface by another distinct aperture (the anus). In most cases, therefore, the alimentary canal is a tube which communicates with the outer world by two apertures—a mouth and anus—but which simply passes through the body-cavity without in any way communicating with it. In the *Cœlenterata* (fig. 35) there is an intermediate condition of parts. There is a distinct and permanent mouth, and a distinct and permanent body-cavity, but the mouth opens into, and communicates freely with, the body-cavity. In some cases (*Hydrozoa*) the mouth opens directly into the general body-cavity, which then serves as a digestive cavity as well (fig. 37). In other cases there intervenes between the mouth and the body-cavity a short alimentary tube, which communicates externally with the outer world through the mouth, and opens below by a wide aperture

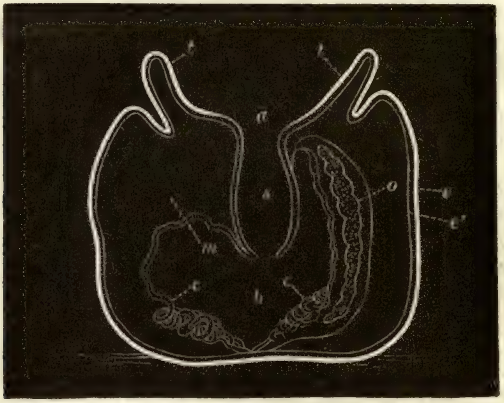

Fig. 35.—Diagrammatic vertical section of a Sea-Anemone. *a* Mouth; *s* Stomach; *b* Body-cavity; *c c* Convoluted cords ("craspeda") containing thread-cells, and forming the free edges of the mesentery (*m*); *t, t* Tentacles; *o* Reproductive organ contained within the mesentery. The ectoderm (*e*) is indicated by the broad external line, the endoderm (*e′*) by the thin line and the space between that and the ectoderm.

into the general cavity of the body (*Actinozoa*, fig. 35). In no case is there a distinct intestinal canal which runs through the body and opens on the surface by a mouth at one end and an excretory aperture or anus at the other. It should, however, be mentioned here that some modern zoologists, such as Gegenbaur and Hæckel, consider that the entire system of internal cavities in any *Cœlenterate* is truly homologous with the intestinal canal of other animals, and that the *Cœlenterata*, therefore, possess no true body-cavity at all. To this view some of our most distinguished authorities, such as Professor Allman, have given their adhesion; and there is no doubt that there are weighty grounds for regarding it as the correct explanation of the facts, though any discussion of these grounds would be out of place here. It need only be added that if this view be accepted, it will entirely subvert the generally received conception of the structure of the *Cœlenterata* as above expressed.

Though of the true "radiate" type, some Cœlenterates show traces of bilateral symmetry. Thus, in some Sea-anemones one of the tentacles is larger than, or differently coloured from, the others; and in some corals two of the primary septa, opposite one another, are larger than the rest, and divide the animal into two halves.

With regard to the fundamental tissues of the *Cœlenterata*, there exist two primary membranes, of which one forms the outer surface of the body, and is called the "ectoderm;" whilst the other lines the alimentary canal, the general cavity of the body, and the tubular tentacles, and is termed the "endoderm." These membranes correspond with the primitive serous and mucous layers ("epiblast" and "hypoblast") of the germinal area, and become differentiated in opposite directions, the ectoderm growing from within outwards, the endoderm from without inwards. Each is primitively cellular in its minute structure, and each may be rendered more or less complex by vacuolation or fibrillation. Between the ectoderm and endoderm there is sometimes a third layer ("mesoderm" or "mesoblast"), which is commonly of a muscular nature.

In connection with the integument of the *Cœlenterata*, the organs termed "thread-cells" ("cnidæ," or "nematocysts") must be noticed. These are peculiar cellular bodies (fig. 36), of various shapes, which probably serve as weapons of offence and defence, and which communicate to many members of the sub-kingdom (*e.g.*, the Sea-blubbers) their well-known power of stinging. In the common *Hydra* the thread-cells (fig. 36, E) consist of "oval elastic sacs, containing a long coiled filament, barbed at its base, and serrated along its edges. When fully developed the sacs are tensely filled with fluid, and the slightest touch is sufficient to cause the retroversion of the filament, which then projects beyond the sac for a distance, which is not uncommonly equal to many times the length of the latter"* (Huxley). Many beautiful modifications of shape are known in the thread-cells of different Cœlenterates, but their essential structure in all cases is much the same as in the Hydra. It is only in few cases, comparatively speaking, that the thread-cells have the power of piercing and irritating the human skin; but even in the diminutive *Hydra* it is probable that they exercise some benumbing and deleterious influence on the living organisms which may be captured as prey. Besides the thread-cells, the tentacles of some Hydroids are furnished with rigid hair-like processes, which are probably tactile in function, and which are known as "palpocils."

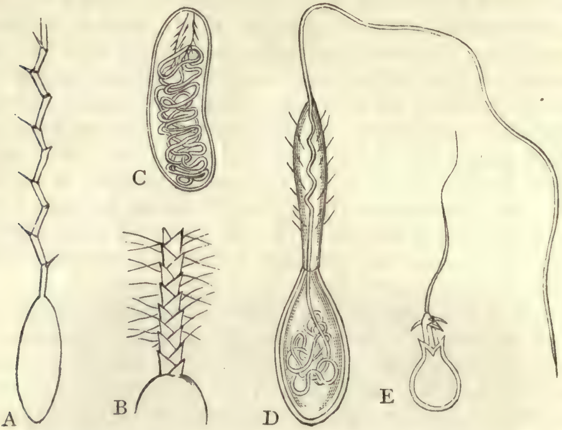

Fig. 36.—Thread-cells of Cœlenterata, greatly magnified. A and B, The thread-cell of *Caryophyllia Smithii*, in the everted condition, and in two varieties; C and D, The thread-cell of *Corallimorphus profundus*, in a quiescent and active condition, enlarged about 500 times; E, The thread-cell of *Hydra*, in an everted condition. (After Gosse and Moseley.)

The *Cœlenterata* are divided into two classes, termed respectively the *Hydrozoa* and the *Actinozoa*.

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* Thread-cells, though very commonly, if not universally, present in the *Cœlenterata*, are nevertheless not peculiar to them. Similar organs have been shown to exist in several of the *Nudibranchiate Mollusca*, as well as in some Annelides (*Spio seticornis*). There likewise exist analogous organs *trichocysts*) in several of the *Infusoria*, and in the *Planarida*.

Class I. Hydrozoa.

The *Hydrozoa* are defined as *Cœlenterata in which the walls of the digestive sac are not separated from that of the general body-cavity, the two coinciding with one another; the reproductive organs are in the form of external processes of the body-wall.* (Fig. 37, B.)

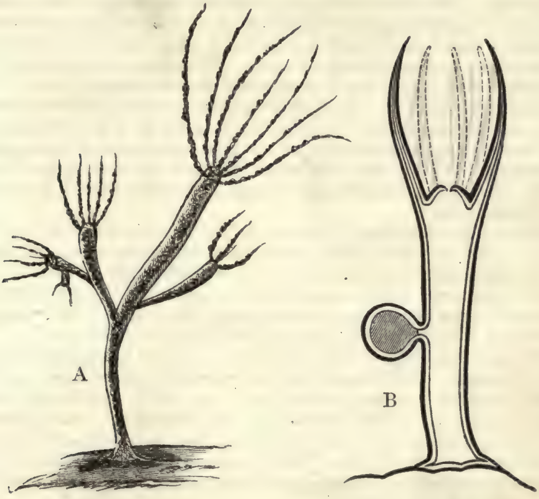

Fig. 37.—A, The common Hydra (*Hydra vulgaris*), carrying young *Hydræ* which it has produced by budding, considerably magnified (after Hincks). B, Diagrammatic section of the *Hydra*, showing the mouth surrounded by the tentacles, and the disc of attachment; the dark and light lines indicate the two layers of the integument, and on one side of the body is shown a single large egg.

It follows from the above, that, since there is but a single internal cavity, the body of a *Hydrozoön* on transverse section appears as a single tube, the walls of which are formed by the limits of the combined digestive and somatic cavity.

The *Hydrozoa* are all aquatic, and the great majority are marine. The class includes both simple and composite organisms, the most familiar examples being the common Fresh-water Polype (*Hydra*), the Sea-firs (*Sertularida*), the Jelly-fishes (*Medusæ*), and the Portuguese man-of-war (*Physalia*).

Owing to the great difficulty which is ordinarily experienced by the student in mastering the details of this class of animals, it has been thought advisable to introduce here a short explanation of some of the technical terms which are in more general use in describing these organisms.

GENERAL TERMINOLOGY OF THE HYDROZOA.

Individual.—We have already seen (*see* Introduction) that the term "individual," in its zoological sense, must be restricted to "the entire result of the development of a single fertilised ovum," and that in this sense an individual may either be simple, like an *Amœba*, or may be composite, like a Sponge, which is produced by an aggregation of amœbiform particles. If all the parts composing an individual remain mutually connected, its development is said to be "continuous;" but if any of these parts become separated as independent beings, the case becomes one of "discontinuous" development. We have seen, also, that however long zoöidal multiplication may go on, there ultimately arrives in the history of every individual a period at which sexual reproduction must be called in to insure the perpetuation of the species throughout time. This truth is expressed by Steenstrup's celebrated law of the "alternation of generations."

Amongst the *Hydrozoa*, the individual may be either simple or compound, and the development may be either continuous or discontinuous, the following terms being employed to denote the phenomena which occur.

Hydrosoma.—This is the term which is employed to designate the entire body of a *Hydrozoön*, whether it be simple, as in the *Hydra*, or composite, as in a *Sertularian.*

Polypite.—The alimentary region of a *Hydrozoön* is called a "polypite;" the term "polype" being now restricted to the same region in the *Actinozoa.* In the simple *Hydrozoa* the entire organism may be called a "polypite;" but the term is more appropriately applied to the separate nutritive factors which together make up a compound *Hydrozoön.* By Professor Allman the term "hydranth" is used in preference to "polypite."

Distal and Proximal.—These are terms applied to different extremities of the hydrosoma. It is found that one extremity grows more quickly than the other, and to this free-growing end—at which the mouth is usually situated—the term "distal" is applied. To the more slowly growing end of the hydrosoma—which is at the same time usually the fixed end—the term "proximal" is applied. These terms may be used either in relation to a single polypite in the compound *Hydrozoa*, or to the entire hydrosoma, whether simple or compound.

Hydrorhiza.—This term is applied to that portion of the proximal end of a Hydroid colony by which it is attached to some foreign body.

Cœnosarc.—This is the term which is employed to designate the common trunk, which unites the separate polypites of any compound *Hydrozoön* into a single organic whole.

Polypary.—The term "polypary" or "polypidom" is applied to the horny or chitinous outer covering or envelope with which many of the *Hydrozoa* are furnished. These terms have also not uncommonly been applied to the very similar structures produced by the much more highly organised Sea-mats and their allies (*Polyzoa*), but it is better to restrict their use entirely to the *Hydrozoa.* By Professor Allman the term "perisarc" is given to the chitinous investment by which the soft parts of the *Hydrozoa* are often protected.

Zoöids.—In continuous development, the partially independent beings which are produced by gemmation or fission from the primitive organism, to which they remain permanently attached, are termed "zoöids." In other words, "zoöids" are the more or less individualised members of which the Hydroid colony is made up.

In discontinuous development, where certain portions of the "individual" are separated as completely independent beings, these detached portions are likewise termed "zoöids;" that which is first formed being distinguished as the "producing zoöid," whilst that which separates from it is known as the "produced zoöid." In a great number of *Hydrozoa* there exist two distinct sets of zoöids, one of which is destined for the nutrition of the colony, and has nothing to do with generation, whilst the functions of the other, as far as the colony is concerned, are wholly reproductive. For *the whole assemblage of the nutritive zoöids of a Hydrozoön* Professor Allman has proposed the term "trophosome," applying the term "gonosome" to *the entire assemblage of the reproductive zoöids.* In such *Hydrozoa*, therefore, as possess these two distinct sets of zoöids, the "individual," zoologically speaking, is composed of a trophosome and a gonosome. It follows from this that neither the trophosome nor the gonosome, however apparently independent, and though endowed with intrinsic powers of nutrition and locomotion, can be looked upon as an "individual," in the scientific sense of this term. As a rule, the zoöids of the trophosome are all like one another, or are "homomorphic;" but there are some cases (as in *Hydractinia*, and in the nematophores of the *Plumularidæ*) in which some of zoöids of the trophosome are unlike the others. The zoöids of the gonosome, on the other hand, are normally unlike, or are "heteromorphic," consisting of two or three different sets of zoöids, each with its special duty in the generative functions of the Hydroid colony.

CHAPTER VIII.

DIVISIONS OF THE HYDROZOA.

SUB-CLASS HYDROIDA.*

THE *Hydrozoa* are divided into five sub-classes—viz., the *Hydroida*, the *Siphonophora*, the *Lucernarida*, the *Graptolitidæ*, and the *Hydrocorallinæ*.

SUB-CLASS I. HYDROIDA.—This sub-class comprises those *Hydrozoa which consist of an alimentary region or "polypite," which is, typically, provided with an adherent disc, or "hydrorhiza," and prehensile tentacles.*

In some few cases the hydrosoma is composed of a single polypite only, as in the *Hydrida* and in some of the *Corynida;* but usually there are several polypites united together by means of a common trunk or "cœnosarc," as in most of the *Corynida* and in the orders *Sertularida* and *Campanularida*. Further, in the great majority of cases, the "hydrorhiza" is permanently attached to some foreign object.

The *Hydroida* comprise six orders—viz., the *Hydrida*, the

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* For full details as to the morphology and physiology of the Hydroid Zoophytes, the student should refer to the magnificent 'Monograph of the Gymnoblastic Hydroids,' by Professor Allman (Ray Society). The student may also consult the excellent 'History of British Hydroid Zoophytes,' by the Rev. Thomas Hincks.

Corynida, the *Sertularida*, the *Campanularida*, the *Thecomedusæ*, and the *Medusidæ*.

ORDER I. HYDRIDA (*Eleutheroblastica*, Allman; *Gymnochroa*, Hincks).—This order comprises those *Hydrozoa whose "hydrosoma" consists of a single locomotive polypite, with tentacles and "hydrorhiza," and with reproductive organs which appear as simple external processes of the body-wall. The hydrorhiza is discoid, and no hard cuticular layer is at any time developed.*

The order *Hydrida* comprises a single genus* only (*Hydra*), including the various species of "Fresh-water Polypes," as they are often called. The common *Hydra* (fig. 37, A) is found abundantly in this country, and consists of a tubular cylindrical body, the "proximal" extremity of which is expanded into an adherent disc or foot—the "hydrorhiza"—by means of which the animal can attach itself to some foreign body. It possesses, however, the power of detaching the hydrorhiza at will, and thus of changing its place. At the opposite or "distal" extremity of the body is placed the mouth, surrounded by a circlet of tentacles, which arise a little distance below the margin of the oral aperture. The tentacles vary in number from five to twelve or more, and they vary considerably in length in different species, being much shorter than the body in the *Hydra viridis* (fig. 38), but being extremely long and

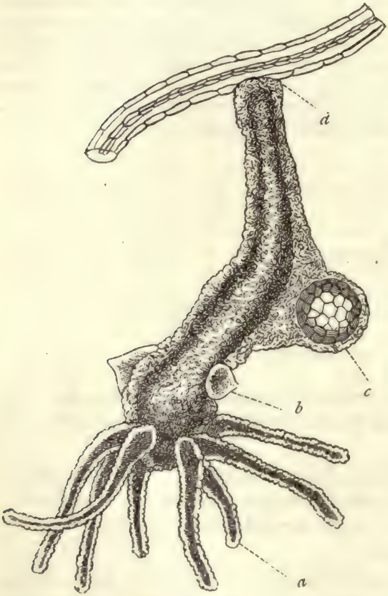

Fig. 38.—The Green Fresh-water Polype (*Hydra viridis*), suspended head-downwards from a piece of a stem of an aquatic plant, enlarged. *a* One of the tentacles; *b* Testis or spermarium, with spermatozoa in its interior; *c* A single large ovum, protruding from the side of the body; *d* Disc of attachment ("hydrorhiza").

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* If the *Protohydra* of Greeff be a mature form, it also belongs to this order. It differs from *Hydra* in having no tentacles, but it seems more probably to be the larva of some other Hydroid.

filamentous in *Hydra fusca.* They are highly extensile and contractile, and serve as organs of prehension, being capable of retraction till they appear as nothing more than so many warts or tubercles, and of being extended to a length which is in some species many times longer than the body itself. (In the *Hydra fusca* the tentacles can be protruded to a length of more than eight inches.) Each consists of a prolongation of both ectoderm and endoderm, enclosing a diverticulum of the somatic cavity, and they are abundantly furnished with thread-cells. The cylindrical hydrosoma (fig. 37, B) is excavated into a single large cavity, lined by the endoderm, and communicating with the exterior by the mouth. This—the "somatic cavity"—is the sole digestive cavity with which the *Hydra* is provided, the indigestible portions of the food being rejected by the mouth.

The *Hydra* possesses a most extraordinary power of resisting mutilation, and of multiplying artificially when mechanically divided. Into however many pieces a *Hydra* may be divided, each and all of these will be developed gradually into a new and perfect polypite. The remarkable experiments of Trembley upon this subject are well known, and have been often repeated, but space will not permit further notice of them here. Reproduction is effected in the *Hydra* both asexually by gemmation, and sexually — the former process being followed in summer, and the latter towards the commencement of winter, few individuals surviving this season. In the first method the *Hydra* (fig. 37, A) throws out one or more buds, generally from near its proximal extremity. These buds at first consist simply of a tubular prolongation of the ectoderm and endoderm, enclosing a cæcal diverticulum of the body-cavity; but a mouth and tentacles are soon developed, when the new being is usually detached as a perfect independent *Hydra.* The *Hydræ* thus produced throw out fresh buds, often before they are detached from the parent organism, and in this way reproduction is rapidly carried on.

In the second or sexual mode of reproduction, ova and spermatozoa are produced in outward processes of the body-wall (fig. 38). The spermatozoa are developed in little conical elevations, which are produced near the bases of the tentacles, and the ova are enclosed in sacs of much greater size, situated nearer the fixed or proximal extremity of the animal. Ordinarily there is but one of these sacs, containing a single ovum, but sometimes there are two. When mature, the ovum is expelled through the body-wall, and is fecundated by the spermatozoa, which are simultaneously liberated. The primitive body-cavity of the non-ciliated embryo is ultimately placed in communication with the outer world by the formation of the mouth, which is produced directly as an opening in the walls of the body, and not by invagination of the ectoderm.

ORDER II. CORYNIDA (*Gymnoblastica*, Allman; *Athecata*, Hincks). — The order *Corynida* comprises those *Hydrozoa whose hydrosoma is fixed by a hydrorhiza, and consists either of a single polypite, or of several united by a cœnosarc, which usually develops a firm outer layer or "polypary." No "hydrothecæ" are present. "The reproductive organs are in the form of gonophores, which vary much in structure, and arise from the sides of the polypites, from the cœnosarc, or from gonoblastidia"* (Greene).

The hydrosoma of the *Corynida* may consist of a single polypite, as in *Coryomorpha* and *Vorticlava*, or it may be composed of several united by a cœnosarc, as in *Cordylophora* (fig. 39, *a*). The order is entirely confined to the sea, with the single exception of *Cordylophora*, which inhabits fresh water. In *Tubularia* and its allies the organism is protected by a well-developed external chitinous envelope or "polypary;" but in the other genera belonging to the order, the polypary is either rudimentary or is entirely absent. The polypary of the *Corynida*, when present, is readily distinguished from that of the *Sertularida*, by the fact that in the former it extends only to the bases of the polypites; whereas in the latter it expands to form little cups for the reception of the polypites, these cups being called "hydrothecæ." Owing to the fact that neither the polypites nor the generative buds of the *Corynida* are en-

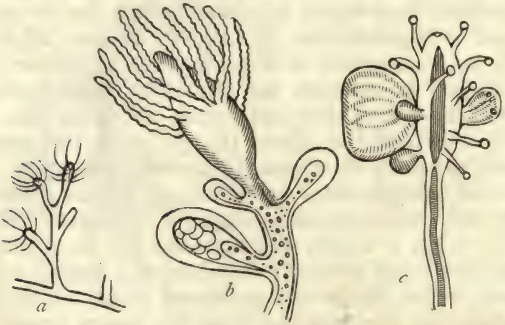

Fig. 39. — Morphology of Corynida. *a* Fragment of *Cordylophora lacustris*, slightly enlarged; *b* Fragment of the same considerably enlarged, showing a polypite and three gonophores in different stages of growth, the largest containing ova; *c* Portion of *Syncoryne Sarsii* with medusiform zoöids budding from between the tentacles.

closed in a chitinous investment, the name of "Gymnoblastic Hydroids" is applied to them by Professor Allman.

As regards the reproductive process in the *Corynida*, the reproductive elements are developed in distinct buds or sacs, which are external processes of the body-wall, and have been aptly termed "gonophores" by Professor Allman. Strictly speaking, Dr Allman understands by the term "gonophore" only the *ultimate* generative zoöid, that which *immediately* produces the generative elements.* Great variations exist in the form and development of these generative buds, and an examination of these leads us to some of the most singular phenomena in the entire animal kingdom. In some species of *Hydractinia* and *Coryne*, the generative buds or "gonophores" exist in their simplest form—namely, as sacciform protuberances of the endoderm and ectoderm, enclosing a diverticulum of the somatic cavity. In this form they are attached to the "trophosome" by a short stalk, and they are termed "sporosacs" (fig. 40). They are exactly like the buds which we have already seen to exist in the *Hydra*, with this difference, that they are not themselves developed into fresh polypites, but are simply receptacles in which the essential elements of generation—the ova and spermatozoa—are prepared, by the union of which the young *Corynid* is produced. The sporosac is almost invariably permanently attached to the trophosome, the only known exception being in *Dicoryne*, in which the sporosac, previous to the discharge of its ova, liberates itself from its outer investment, and swims about freely as an independent ciliated organism.

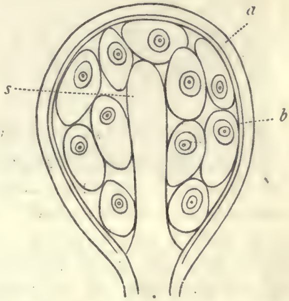

Fig. 40.—Sporosac of *Hydractinia echinata* (after Allman). *a* Outer wall of the sac; *b* inner wall of the sac; *s* Column developed from the floor of the sporosac, and extending into its cavity. This is termed the "spadix;" it contains a prolongation from the cœnosarcal canal, and the ova are developed around it.

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* According to Mr Hincks, the "gonophore" is the bud in which the reproductive elements are formed. "It consists of an external envelope (ectotheca), enclosing *either* a fixed generative sac between the walls of which the ova and spermatozoa are developed, *or* a free sexual zoöid." The actual sexual zoöid is termed by Mr Hincks the "gonozoöid," whether it be fixed or free—in other words, it is the gonophore *minus* its external investment. The gonozoöid is sometimes male, sometimes female; and the same colony may produce one or both—the former being most commonly the case.

In *Cordylophora* (fig. 41, *b*) a further advance in structure is perceptible. The gonophore now consists of a closed sac, from the roof of which depends a hollow process or peduncle—the "manubrium"—which gives off a system of tubes which run in the walls of the sac. For reasons which will be immediately evident, the gonophore in this case is said to have a "disguised" medusoid structure (fig. 41, *b*).

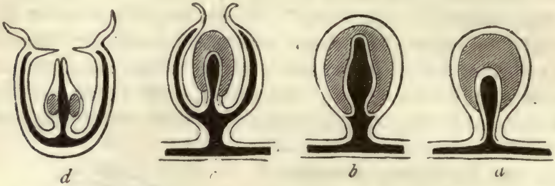

Fig. 41.—Reproductive processes of Hydrozoa. *a* Sporosac; *b* Disguised medusoid; *c* Attached medusiform gonophore; *d* Free medusiform gonophore. The cross shading indicates the reproductive organs, ovaria or spermaria. The part completely black indicates the cavity of the manubrium and the gonocalycine canals.

In certain *Corynida*, however, we meet with a still higher form of structure, the gonophores being now said to be "medusoid." In these cases the generative bud is primitively a simple sac—such as the "sporosac"—but ultimately develops itself into a much more complicated structure. The gonophore (fig. 41, *c*) is now found to be composed of a bell-shaped disc, termed the "gonocalyx," which is attached by its base to the parent organism (the trophosome), and has its cavity turned outwards. From the roof of the gonocalyx, like the clapper of a bell, there depends a peduncle or "manubrium," which contains a process of the somatic cavity. The manubrium gives out at its fixed or proximal end four prolongations of its cavity, in the form of radiating lateral tubes which run to the margin of the bell, where they communicate with one another by means of a single circular canal which surrounds the mouth of the bell. This system of tubes constitutes what is known as the system of the "gastro-vascular" or "gonocalycine canals." The gonophore, thus constituted, may remain permanently attached to the parent organism, as in *Tubularia indivisa* (fig. 41, *c*); but in other cases still further changes ensue. In the higher forms of development (fig. 42) the manubrium acquires a mouth at its free or distal extremity, and the gonocalyx becomes detached from the parent. The gonophore is now free, and behaves in every respect as an independent being. The gonocalyx is provided with marginal tentacles and with an inward prolongation from its margin, which partially closes the mouth of the bell, and is termed the "veil" or "velum." By the contractions of the gonocalyx, which now serves as a natatorial organ, the gonophore is propelled through the water. The manubrium, with the shape, assumes the functions of a polypite, and its cavity takes upon itself the office of a digestive sac. Growth is rapid, and the gonophore may attain a comparatively gigantic size, being now absolutely identical with one of those organisms which are commonly called "jelly-fishes," and are technically known as *Medusæ* (fig. 42). In fact, as we shall afterwards see, many of the *gymnophthalmate Medusæ*, originally described as a distinct order of free-swimming Hydrozoa, are in truth merely the liberated generative buds, or "medusiform gonophores," of the permanently rooted *Hydroids*. Finally, the essential generative elements—the ova and spermatozoa—are developed in the walls of the manubrial sac, between its endoderm and ectoderm, and embryos are produced. These embryos, however, instead of resembling the organism which immediately gave them birth, develop themselves into the fixed *Corynid* from which the gonophore was produced, thus completing the cycle.

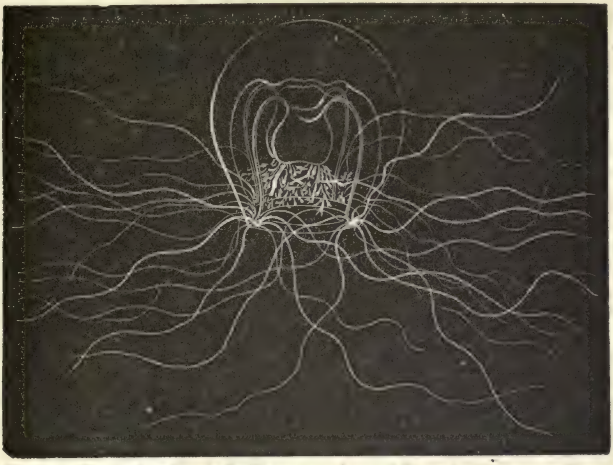

Fig. 42.—Free-swimming medusiform gonophore of *Bougainvillea superciliaris* a fixed Hydroid. Enlarged. (After A. Agassiz.)

The swimming-bell of the medusiform gonophore is believed to be formed by a great development of an inter-tentacular web, such as is sometimes present, in a rudimentary form, in the nutritive zoöids. Sometimes the medusoid becomes quiescent towards the close of its existence, and the swimming-bell becomes reversed or atrophied. Lastly, in *Clavatella*, the sexual zoöid, though free and locomotive, is not provided with a swimming-bell, but creeps about by means of suctorial discs developed on branches of the tentacles.

As we have seen, the generative buds of the *Corynida* may exist in the following chief forms: 1. As "sporosacs," or simple closed sacs, consisting of ectoderm and endoderm, with a central cavity in which ova and spermatozoa are produced. 2. As "disguised medusoids," in which there is a central manubrial process and a rudimentary system of gonocalycine canals; but the gonocalyx remains closed. 3. As complete medusoids, which have a central manubrium, a complete system of gonocalycine canals, and an open gonocalyx; but which never become detached. 4. As perfect medusiform gonophores (fig. 42), which are detached, and lead an independent existence for a time, until the generative elements are matured. In whichever of these forms the gonophore may be present, the place of its origin from the trophosome may vary in different species of the order. 1. They may arise from the sides of the polypites, as in *Coryne* and *Stauridia;* 2. They may be produced from the cœnosarc, as in *Cordylophora;* 3. They may be produced upon certain special processes, which are termed "gonoblastidia," as in *Hydractinia* and *Dicoryne.* These gonoblastidia (fig. 43, *g*) are processes from the body-wall or cœnosarc, which closely resemble true polypites in form, but differ from them in being usually devoid of a mouth, and in having shorter tentacles. They are, in truth, atrophied or undeveloped polypites.

The gonoblastidia are the "blastostyles" of Prof. Allman, and are usually columniform in shape. They may carry sporosacs, or medusoid gonophores; and they may be naked, or, in other orders, they may be protected within a chitinous receptacle or "gonangium."

As regards the development of the *Corynida*, the embryo is very generally, though not always, ciliated at first, when it is known as a "planula;" but in one form the embryo leaves the gonophore as a free and locomotive polypite, and in another it is non-ciliated and amœboid. The "planula" is a minute ciliated cylindrical body, which swims about actively in the water. The embryonic cells of which it is composed divide into an outer and an inner layer, enclosing a central cavity, and it next passes into a condition which is common to the embryos of the *Cœlenterata* generally, and to which Hæckel has applied the name of "gastrula." At this stage, it consists of an ovate or rounded body, with a single central cavity, which communicates with the exterior by an aperture placed at one pole. The wall of this central cavity consists of two layers, an outer and an inner, corresponding with the ectoderm and endoderm of the adult, and also with the two primitive layers of the germ of the *Vertebrata*. The "gastrula" stage appears to be one very generally passed through by all animals higher than the *Protozoa*, and by the Sponges amongst the latter, but there is a difference as to the manner in which the central cavity is formed.

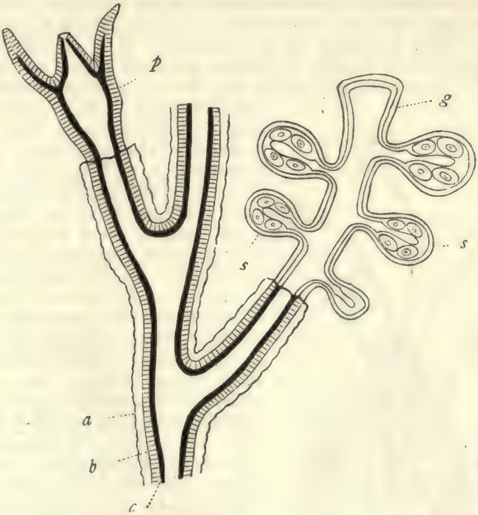

Fig. 43.—Diagram of sporosacs supported upon a gonoblastidion (or blastostyle). *a* Chitinous investment (periderm) of the colony; *b* Ectoderm; *c* Endoderm; *p* Polypite; *g* Gonoblastidion, or columniform zoöid, carrying sporosacs (*s s*) with ova in their interior. (Altered from Allman.)

In some cases it is formed by the hollowing out of the original sphere, and the formation of an opening (the primitive mouth) at one end, as seems to be generally the case in the *Cœlenterata;* or, in other cases, it may be produced by an invagination or inversion of the primitive vesicle in such a manner as to form a central chamber, with a single aperture opening on the exterior. By fixation of the "gastrula" at its hinder extremity to some foreign object, and by the formation of tentacles round the mouth-opening at the other extremity, a hydraform polypite is at once produced, which (if not belonging to one of the simple forms) proceeds to develop the composite adult by a process of gemmation. In this process in the *Corynida* (as also in the *Sertularida* and *Campanularida*) the new polypites are developed at or near the distal end of the hydrosoma, the distal polypites being thus the youngest; whereas the reverse of this obtains amongst the Oceanic *Hydrozoa*.

The subject of the reproduction of the *Corynida* having been treated at some length, so as to apply to the remaining *Hydroida*, we shall now give a brief description of the leading types of structure exhibited by the order.

Eudendrium, a genus of the *Corynida*, which is not uncommonly found attached to submarine objects, usually in tolerably deep water, may be taken as a good example of the fixed and composite division of the order. The hydrosoma consists of numerous polypites, united by a cœnosarc, which is more or less branched, and is defended by a horny tubular polypary. The polypites are borne at the ends of the branches and branchlets, and are not contained in "hydrothecæ," the polypary ending abruptly at their bases. The polypites are non-retractile, of a reddish colour, and provided with about twenty tentacles, arranged round the mouth in a single row. *Tubularia* (fig. 44) is very similar to *Eudendrium*, but the hydrosoma is either undivided or is very slightly branched. The hydrosoma consists of clustered horny tubes, of a straw colour, and not unlike straws to look at; hence the common name of pipe-coralline given to this zoophyte. Each tube is filled with a soft, semifluid, reddish cœnosarc, and gives exit at its distal extremity to a single polypite. The polypites are bright red in colour, and are not retractile within their tubes, the horny polypary extending only to their bases. The polypites are somewhat conical in shape, the mouth being placed at the apex of the cone, and they are furnished with two sets of tentacles. One set consists of numerous short tentacles placed directly round the mouth; the other is composed of from thirty to forty tentacles of much greater length, arising from the polypite about its middle or near the base. Near the insertion of these tentacles the generative buds are produced at proper seasons. The generative buds remain permanently attached, but each is furnished with a swimming-bell, in which canals are present. The manubrium is destitute of a mouth, and "the swimming-bell is converted into a nursery in which the embryo passes through the later stages of its development" (Hincks).

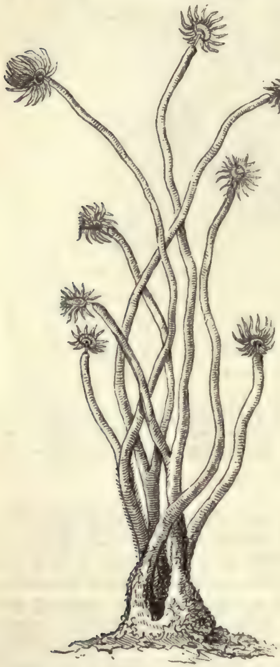
Fig. 44. — Corynida. Fragment of *Tubularia indivisa*, natural size.

Coryomorpha nutans may be taken to represent those *Corynida* in which there is no polypary and the hydrosoma is simple. It is about four inches in length, and is fixed by filamentous roots to the sand at the bottom of the sea. It consists of a single whitish polypite, striped with pink, and terminating upwards in a spear-shaped head, round the thickest part of which is a circlet of from forty to more than one hundred long white tentacles. Above these comes a series of long, branching gonoblastidia, bearing gonophores, and succeeded by a second shorter set of tentacles which surround the mouth. The gonophores become ultimately detached as free-swimming medusoids.

Another remarkable example of the *Corynida* is *Hydractinia* (fig. 45). In this genus the polypites are gregarious, and the polypary forms a horny crust which spreads over shells and other foreign bodies. The tentacles of the nutritive zoöids form a single sub-alternate series. The generative buds are produced upon imperfect, non-tentaculate polypites; and are mere sac-shaped protuberances, enclosing diverticula from the body-cavity, but not detached from the parent organism.

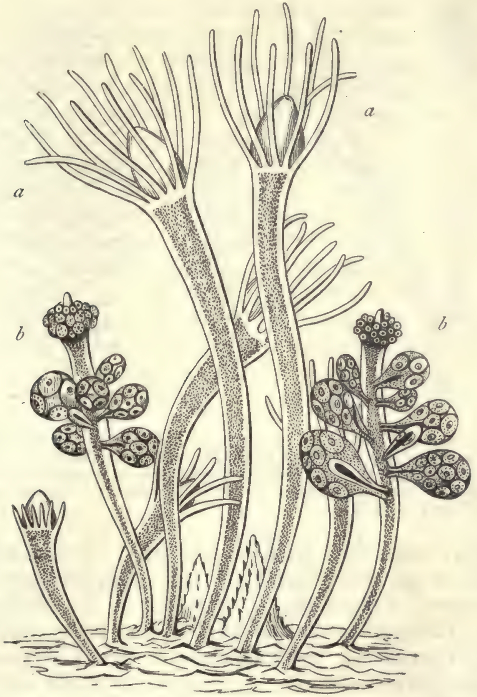

Fig. 45.—Group of zoöids of *Hydractinia echinata*, enlarged. (After Hincks.) *a a* Nutritive zoöids; *b b* Generative zoöids, carrying sacs filled with ova.

ORDER III. SERTULARIDA (*Calyptoblastica*, Allman; *Thecaphora*, Hincks).—This order comprises those Hydrozoa "*whose hydrosoma is fixed by a hydrorhiza, and consists o several polypites, protected by hydrothecæ, and connected by a cœnosarc, which is usually branched and invested by a very firm outer layer. Reproductive organs in the form of gonophores arising from the cœnosarc or from gonoblastidia*" (Greene).

The *Sertularida* resemble the *Corynida* in becoming permanently fixed after their embryonic condition by a hydrorhiza, which is developed from the proximal end of the cœnosarc;

but they differ in the fact that the polypites are invariably protected by "hydrothecæ," or little cup-like expansions of the polypary (fig. 46, *a*, *b*); whilst the hydrosoma is in all cases

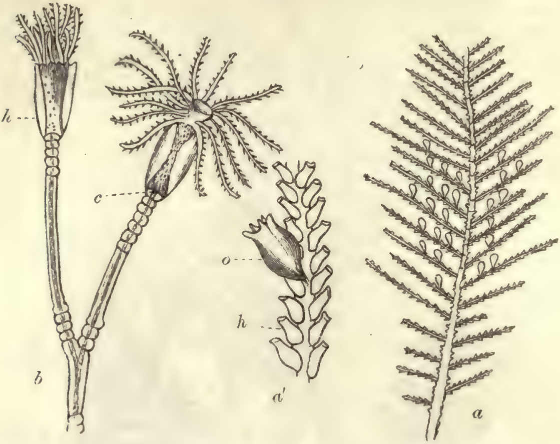

Fig. 46.—*a Sertularia* (*Diphasia*) *pinnata*, natural size ; *a′* Fragment of the same enlarged, carrying a male capsule (*o*), and showing the hydrothecæ (*h*); *b* Fragment of *Campanularia neglecta* (after Hincks), showing the polypites contained in their hydrothecæ (*h*), and also the point at which the cœnosarc communicates with the stomach of the polypite (*c*).

composed of more than a single polypite. The mouth of the hydrotheca is generally furnished with an operculum or valve for its closure. Owing to the presence of "hydrothecæ," the name of "Calyptoblastic Hydroids" has been proposed by Professor Allman for the Sertularians and Campanularians. In all these forms, also, the generative buds are similarly enclosed in chitinous receptacles—the so-called "gonothecæ" or "gonangia." The cœnosarc generally consists of a main stem—or "hydrocaulus"—with many branches; and it is so plant-like in appearance that the common Sertularians are almost always mistaken for sea-weeds by visitors at the seaside. It is invested by a strong corneous or chitinous covering, often termed the "periderm."

The polypites are sessile or sub-sessile, hydra-form, and in all essential respects identical with those of the *Corynida*, though usually smaller. Each polypite consists of a soft, contractile and extensile body, which is furnished at its distal extremity with a mouth and a circlet of prehensile tentacles, richly furnished with thread-cells. The tentacles have an indistinctly alternate arrangement. The mouth is simple or lobed, and is placed, in many cases, at the extremity of a more or less prominent extensile and contractile proboscis. The mouth opens into a chamber which occupies the whole length of the polypite, and is to be regarded as the combined body-cavity and digestive sac. At its lower end this chamber opens by a constricted aperture into a tubular cavity which is everywhere excavated in the substance of the cœnosarc (fig. 46, *b*). The nutrient particles obtained by each polypite thus serve for the support of the whole colony, and are distributed throughout the entire organism. The nutritive fluid prepared in the interior of each polypite gains access through the above-mentioned aperture to the cavity of the cœnosarc, which by the combined exertions of the whole assemblage of polypites thus becomes filled with a granular nutritive liquid. The cœnosarcal fluid is in constant movement, circulating through all parts of the colony, and thus maintaining its vitality, the cause of the movement being probably due in part, at any rate, to the existence of vibrating cilia. The generative buds (gonophores or ovarian vesicles) are usually supported upon gonoblastidia, and do not become detached in the true Sertularids. They are developed in chitinous receptacles known as "gonothecæ" (figs. 47, 48).

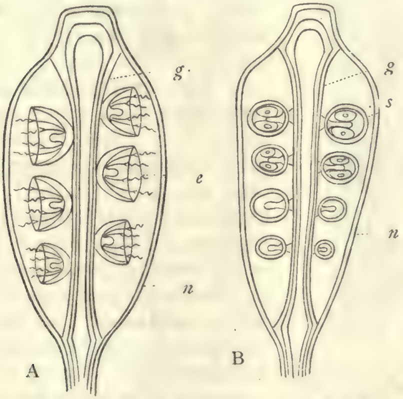

Fig. 47.—Diagrams of the gonothecæ, with their contents, of the Sertularians and Campanularians. *n* Chitinous envelope; *g* Central gonoblastidion or blastostyle; *e* Medusiform gonophores carried upon the blastostyle, each with a central manubrium, in the walls of which the generative elements are produced; *s* Sporosacs carried upon the blastostyle, each with a central pillar (spadix), round which the ova are developed. (Altered from Allman.)

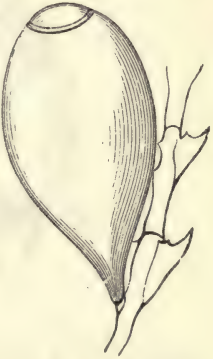

Fig. 48.—Ovarian capsule of *Diphasia* (*Sertularia*) *operculata*, Linn. (after Hincks). Greatly enlarged.

Sometimes the "gonangium" or "gonotheca" contains only a single gonophore, but more commonly it contains several, which increase in maturity as we recede from the base of the gonoblastidion (or blastostyle) and approach its summit (fig. 47, B). The buds carried on the sides of the blastostyle may have the form either of sporosacs or of medusoids. The ova may be directly discharged into the surrounding water, or may be retained for some time in a peculiar receptacle, "where they undergo further development, and which is supported upon the summit of the gonangium, and lies entirely external to its cavity" (Allman).

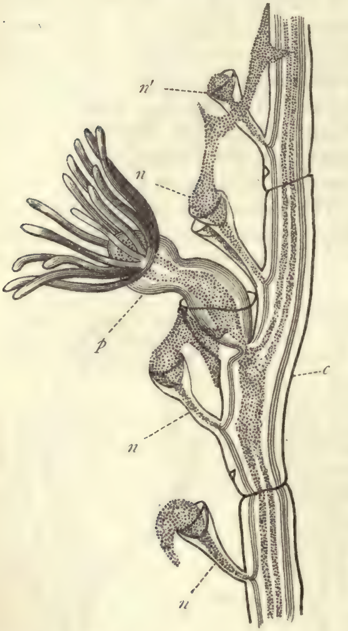

Fig. 49.—Portion of a branch of *Antennularia antennina*, enlarged. (After Allman.) *p* One of the polypites; *n n n* Nematophores emitting pseudopodial filaments of sarcode; *n'* Nematophore with its sarcodic contents quiescent; *c* Cœnosarc enclosed within the polypary.

In *Plumularia* and some of its allies there occur certain peculiar structures, to which the name of "nematophores" has been applied. Each of these consists of a process of the cœnosarc, which is invested by the horny polypary, with the exception of the distal extremity, which remains open. The nematophores are sometimes fixed, sometimes movable. They "constitute cup-like appendages (fig. 49, *n n*) formed of chitine, and filled with protoplasm, which has the power of emiting pseudopodia or amœboid prolongations of its substance, and having their cavity in communication with that of the common tube of the hydrocaulus" (Allman). Whilst part of the sarcode in each nematophore is capable of being extended in long filaments resembling the pseudopodia of an *Amœba*, another portion is charged with large thread-cells, and is not capable of emission in this way. The function of these extraordinarily modified zoöids is uncertain.

Order IV. Campanularida.—The members of this order are closely allied to the *Sertularida*; so closely, indeed, that they are very often united together into a single group. The chief difference consists in the fact that the hydrothecæ of the *Campanularida*, with their contained polypites, are supported upon conspicuous stalks, thus being terminal in position (figs. 46, *b*, and 50); whilst in the *Sertularida* they are sessile or subsessile, and are placed laterally upon the branchlets. The gonophores also in the *Campanularida* are usually detached as free-swimming medusoids, whereas they remain permanently attached in the *Sertularians*. Each medusoid consists of a

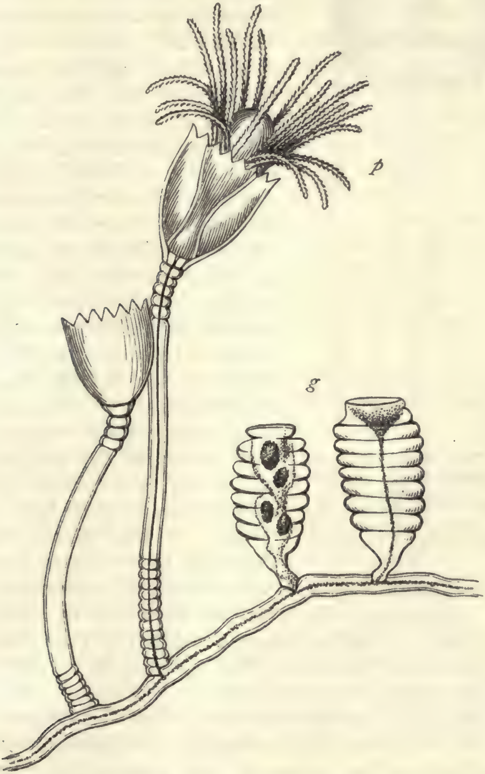

Fig. 50.—Portion of the colony of *Clytia* (*Campanularia*) *Johnstoni*, magnified. *p* Nutritive zoöid; *g* Capsules in which the reproductive zoöids are produced.

little transparent glassy bell, from the under surface of which there is suspended a modified polypite, in the form of a "manubrium" (fig. 51). The whole organism swims gaily through the water, propelled by the contractions of the bell or disc (*gonocalyx*); and no one would now suspect that it was in any way related to the fixed plant-like zoophyte from which it was originally budded off. The central polypite is furnished with a mouth at its distal end, and the mouth opens into a digestive sac. From the proximal end of this stomach proceed four radiating canals which extend to the circumference of the disc, where they all open into a single circular vessel surrounding the mouth of the bell. From the margins of the disc hang also a number of delicate extensile filaments or tentacles; and the circumference is still further adorned with a series of brightly-coloured spots, which are probably organs of sense. The mouth of the bell is partially closed by a delicate transparent membrane or shelf, the so-called "veil." Thus constituted, these beautiful little beings lead an independent and locomotive existence for a longer or shorter period. Ultimately, the essential elements of reproduction are developed in special organs, situated in the course of the radiating canals of the disc. The resulting embryos are ciliated and free-swimming, but ultimately fix themselves, and develop into the plant-like colony from which fresh medusoids may be budded off. The ova in the medusiform gonophores are usually developed in the course of the gonocalycine canals, and not between the ectoderm and endoderm of the manubrium, as is the case in the *Corynida*. Examples of the order are *Campanularia*, *Laomedea*, &c. The distinctions between the *Sertularida* and *Campanularida* are certainly insufficient to justify their being placed in separate orders. If united together, it would probably be best to adopt the name of *Calyptoblastica* (Allman) or *Thecaphora* (Hincks) for the order, and

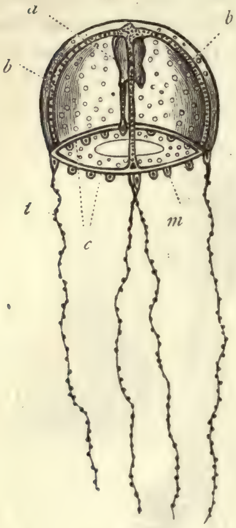

Fig. 51. — Free medusiform gonophore of *Clytia Johnstoni* (after Hincks). *a* Central polypite or manubrium; *b b* Radiating gastro-vascular canals; *c* Circular canal; *m* Marginal bodies; *t* Tentacles.

to employ the names *Sertularida* and *Campanularida* for the sub-orders.

ORDER V. THECOMEDUSÆ.—Professor Allman has recently described under the name of *Stephanoscyphus mirabilis*, a very remarkable Hydrozoön, which he believes to form the type of a new order. This singular organism is invariably associated with a species of Sponge, in the substance of which it is embedded. It consists of a congeries of chitinous tubes, which permeate the sponge-substance, and which open on its surface by large openings resembling oscula. At their bases the tubes are connected by horizontal branches, and they expand widely as they approach the surface; where their contents become developed into a remarkable body, which has the power of extending itself beyond the mouth of the tube, and again of withdrawing within it. This body is furnished with a crown of tentacles, and is essentially *medusiform* in its structure. There is a circular canal at the base of the tentacular crown, surrounding the central opening, with four radiating canals proceeding backwards from this; but no lithocysts, ocelli, nor velum have been detected. For this curious organism, Professor Allman proposes the formation of a new order under the name of *Thecomedusæ.*

ORDER VI. MEDUSIDÆ or HYDROMEDUSIDÆ (*Acalephæ** in part).—The organisms included in this order have often been separated as a distinct sub-class of the *Hydrozoa;* but they are, perhaps, best regarded as a mere order of the Hydroid Zoophytes, characterised by the fact that *the hydrosoma is free-swimming and oceanic, consisting of a single swimming-bell* ("*nectocalyx*"), *from the roof of which is suspended a single polypite. A system of canals is developed in the walls of the swimming-bell, and the reproductive organs are processes of the sides of these canals or of the walls of the polypite.*

The *Medusidæ* comprise most of the smaller organisms commonly known as Jelly-fishes or Sea-nettles, the last name being derived from the property which some of them possess of severely stinging the hand, this power being due to the presence of numerous thread-cells. As employed by modern naturalists, the order is very much restricted, many of its members having been shown to be really the free generative buds of other *Hydrozoa*. As used here, it corresponds to part of the *Gymnophthalmate Medusæ* of Professor E. Forbes, the *Steganophthalmate Medusæ* of the same author being now placed in the sub-class *Lucernarida*.

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* The old sub-class of the *Acalephæ* contained the *Gymnophthalmate Medusæ* (= the *Discophora*), and the *Steganophthalmate Medusæ* (= the *Lucernarida* in part), the two being placed in a single order under the name of *Pulmograda.* The *Acalephæ* also contained the *Ctenophora* and the *Calycophoridæ* and *Physophoridæ*, of which the former constituted the order *Ciliograda*, whilst the two latter made up the order *Physograda.* The *Ctenophora*, however, are now generally placed amongst the *Actinozoa*, whilst the *Calycophoridæ* and *Physophoridæ* constitute the Hydrozoal sub-class *Siphonophora.*

The hydrosoma of one of the *Medusidæ* (= a Gymnophthalmate *Medusa*) is composed of a single, gelatinous, bell-shaped swimming organ, the "nectocalyx" or "disc," from the roof of which a single polypite is suspended (figs. 52, 53). The interior of the nectocalyx is often called the "nectosac," and the term "codonostoma" has been proposed to designate the open mouth of the bell. The margin of the nectocalyx is produced inwards to form a species of shelf, running round the margin of the mouth of the bell, and termed the "veil" or "velum," by the presence of which the nectocalyx is distinguished from the somewhat similar "umbrella" of the *Lucernarida*. The endodermal lining of the central polypite or "manubrium" (sometimes called the "proboscis") is prolonged into four, sometimes more, radiating canals, which run to the periphery of the nectocalyx, where they are connected by a circular canal which runs round its circumference, the whole constituting the system of the "nectocalycine canals" (often called the "chylaqueous" or "gastro-vascular canals"). From the circumference of the nectocalyx depend marginal

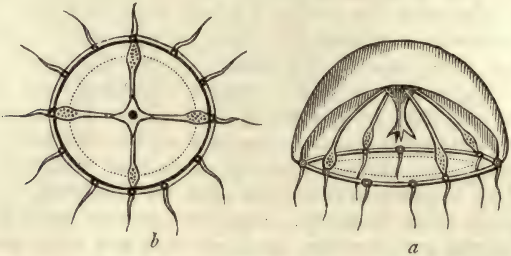

Fig. 52.*—Morphology of Medusidæ. *a* A Medusoid (*Thaumantias*) seen in profile, showing the central polypite, the radiating and circular gonocalycine canals, the marginal vesicles and tentacles, and the reproductive organs; *b* The same viewed from below. The dotted line indicates the margin of the velum.

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* The form here figured (fig. 52), though in all respects anatomically identical with the true *Medusæ*, and originally described as such, is now known to be in reality the medusoid bud of a fixed Hydroid. It illustrates the structure and form of the *Medusæ*, however, just as well as though it were completely independent in its development.

tentacles, which are usually hollow processes, composed of both ectoderm and endoderm, and in immediate connection with the canal system. Also round the circumference of the nectocalyx are disposed certain "marginal bodies," of which two kinds may be distinguished. Of these the first are termed "vesicles," and consist of rounded sacs lined by epithelium, and containing one or more solid, motionless concretions—apparently of carbonate of lime—immersed in a transparent fluid. The second class of marginal bodies, variously termed "pigment-spots," "eye-specks," or "ocelli," consists of little aggregations of pigment enclosed in distinct cavities. The "vesicles" are probably rudimentary organs of hearing, and possibly the eye-specks are a rudimentary form of visual apparatus. The oral margin of the polypite may be simple, or it may be produced into lobes, which are most frequently four in number. The essential elements of generation are produced in simple expansions either of the wall of the manubrium or of the radiating nectocalycine canals.

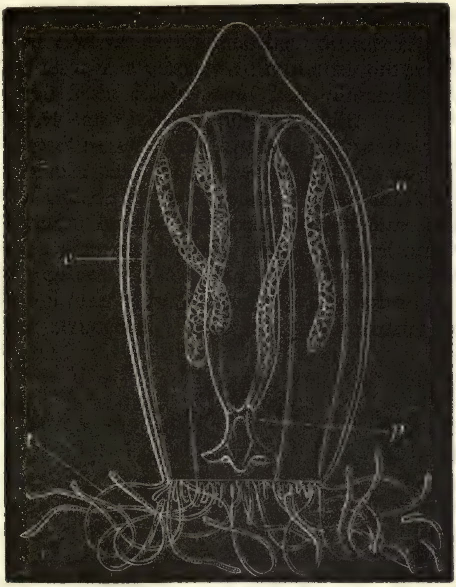

Fig. 53.—*Trachynema digitale*, a naked-eyed Medusa, female, enlarged. (After A. Agassiz.) *p* Manubrium or central polypite; *t* One of the tentacles; *c* One of the gastro-vascular canals; *o* One of the ovaries.

From the above description it will be evident that the *Medusa* is in all essential respects identical in structure with the free-swimming generative bud or gonophore of many of the fixed and oceanic *Hydrozoa*. Indeed, a great many forms which were previously included in the *Medusidæ* have now been proved to be really of this nature; and it is only in a comparatively small number of *Medusæ* that the direct mode of development which alone would entitle them to be ranked as independent organisms has been observed. The *Trachynemidæ*, *Æginidæ*, and *Geryonidæ* appear, however, to be directly developed from the ovum, and are therefore properly placed in the present order; while we may temporarily include here a number of Medusoid forms, the development of which is at present unknown.

As to the development of these true *Medusidæ*, little is known for certain. It appears, however, that in *Trachynema*, *Æginopsis*, and other genera, the embryo is directly developed into a form resembling its parent, without passing through any intermediate changes of form. It is hardly necessary to remark that this is not the case with the embryos of a medusiform gonophore, these being developed into the sexless *Hydrozoön* by which the medusoid was produced. It has also been shown that various of the true *Medusæ* (*Cunina*, *Ægineta*, &c.), have the power of producing new forms like themselves by a process of budding, the phenomena attendant upon this being sometimes of great interest.

In this connection, allusion may be made to the long-known fact that certain "medusiform gonophores" are likewise capable of producing independent forms directly resembling themselves by a process of gemmation, and not by one of true reproduction. Technically these are called "tritozoöids," as being derived from organisms which are themselves but the generative zoöids of another being. This singular phenomenon has been observed in various medusiform gonophores (*e.g.*, *Sarsia gemmifera*), the buds springing in different species from the gonocalycine canals, from the tentacles, or from the sides of the polypite or manubrium.

The "naked-eyed" *Medusæ* and their allies the "medusiform gonophores," though mostly very diminutive in point of size, are exceedingly elegant and attractive when examined in a living condition, resembling little bells of transparent glass adorned here and there with the most brilliant colours. They occur in their proper localities and at proper seasons in the most enormous numbers. They are mostly phosphorescent, or capable of giving out light at night, and they appear to be one of the principal sources of the luminosity of the sea. It does not seem, however, that they phosphoresce, unless irritated or excited in some manner.

CHAPTER IX.

SIPHONOPHORA.

SUB-CLASS II. SIPHONOPHORA.—The members of this subclass constitute the so-called "Oceanic *Hydrozoa;*" and are characterised by the possession of a "*free and oceanic hydrosoma, consisting of several polypites united by a flexible, contractile, unbranched or slightly-branched cœnosarc, the proximal end of which is usually furnished with 'nectocalyces,' and is dilated into a 'somatocyst' or into a 'pneumatophore'*" (Greene).

All the *Siphonophora* are unattached, and permanently free, and all are composite. They are singularly delicate organisms, mostly found at the surface of tropical seas, the Portuguese man-of-war (*Physalia*) being the most familiar member of the group. The sub class is divided into two orders—viz., the *Calycophoridæ* and the *Physophoridæ.*

ORDER I. CALYCOPHORIDÆ.—This order includes those *Siphonophora* whose *hydrosoma is free and oceanic, and is propelled by "nectocalyces" attached to its proximal end. The hydrosoma consists of several polypites, united by an unbranched cœnosarc, which is highly flexible and contractile, and never develops a hard cuticular layer. The proximal end of the hydrosoma is modified into a peculiar cavity called the "somatocyst." The reproductive organs are in the form of medusiform gonophores produced by budding from the peduncles of the polypites.*

In all the *Calycophoridæ* the cœnosarc is filiform, cylindrical, unbranched, and highly contractile, this last property being due to the presence of abundant muscular fibres. "The proximal end of the cœnosarc dilates a little, and becomes ciliated internally, forming a small chamber" which communicates with the nectocalycine canals. "At its upper end this chamber is a little constricted, and so passes, by a more or less narrowed channel, into a variously-shaped sac, whose walls are directly continuous with its own, and which will henceforward be termed the *somatocyst* (fig. 54, 3 *b*). The endoderm of this sac is ciliated, and it is generally so immensely vacuolated as almost to obliterate the internal cavity, and give the organ the appearance of a cellular mass" (Huxley). The polypites in the *Calycophoridæ* often show a well-marked division into three portions, termed respectively the proximal, median, and distal divisions.

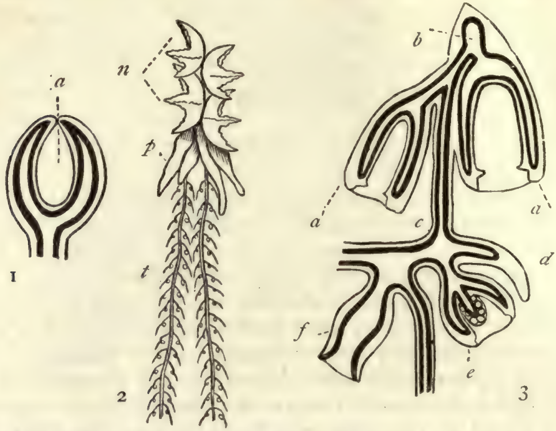

Fig. 54.—Morphology of the Oceanic Hydrozoa. 1. Diagram of the proximal extremity of a *Physophorid; a* Pneumatocyst. 2. *Vogtia pentacantha*, one of the *Calycophoridæ: n* Nectocalyces; *p* Polypites; *t* Tentacles. 3. Diagram of a *Calycophorid: a a'* Proximal and distal nectocalyces; *b* Somatocyst; *c* Cœnosarc; *d* Hydrophyllium or bract; *e* Medusiform gonophore; *f* Polypite. The dark lines in figs. 1 and 3 indicate the endoderm, the light line with the clear space indicates the ectoderm. (After Huxley.)

Of these the "proximal" division is somewhat contracted, and forms a species of peduncle, which often carries appendages. The "median" portion is the widest, and may be termed the "gastric division," as in it the process of digestion is carried on. It is usually separated from the proximal division by a valvular inflection of the endoderm, which is known as the "pyloric valve." The polypites have only one tentacle "developed near their basal or proximal ends, and provided with lateral branches ending in saccular cavities," and furnished with numerous thread-cells. The proximal ends of the polypites usually bear certain overlapping plates of a protective nature, which are termed "hydrophyllia" or "bracts." They are composed of processes of both ectoderm and endoderm (fig. 54, 3 *d*), and they always contain a diverticulum from the somatic cavity, which is called a "phyllocyst." The *Calycophoridæ* always possess swimming-bells, or "nectocalyces," by the contractions of which the hydrosoma is propelled through the water (fig. 54, 2). The nectocalyx in structure is very similar to the "gonocalyx" of a medusiform gonophore, as already described; but the former is devoid of the gastric or genital sac—the "manubrium"—possessed by the latter. Each nectocalyx consists of a bell-shaped cup, attached by its base to the hydrosoma, and provided with a muscular lining in the interior of its cavity, or "nectosac." There is also always a "velum" or "veil," in the form of a membrane attached to the mouth of the nectosac round its entire margin, and leaving a central aperture. The peduncle by which the nectocalyx is attached to the hydrosoma conveys a canal from the somatic cavity which dilates into a ciliated chamber, and gives off at least four radiating canals, which proceed to the circumference of the bell, where they are united by a circular vessel; the entire system constituting what is known as the system of the "nectocalycine canals." In the typical *Calycophoridæ* two nectocalyces only are present, but in some genera there are more. In *Praya* the two nectocalyces are so apposed to one another that a sort of canal is formed by the union of two grooves, one of which exists on the side of each nectocalyx. This chamber, which is present in a more or less complete form in all the genera, is termed the "hydrœcium," and the cœnosarc can be retracted within it for protection.

The reproductive bodies in the *Calycophoridæ* are in the form of medusiform gonophores, which are budded from the peduncles of the polypites, becoming, in many instances, detached to lead an independent existence. In some *Calycophoridæ*, as in *Abyla*, "each segment of the cœnosarc, provided with a polypite, its tentacle, reproductive organ, and hydrophyllium, as it acquires a certain size, becomes detached, and leads an independent life—the calyx of its reproductive organ serving it as a propulsive apparatus. In this condition it may acquire two or three times the dimensions it had when attached, and some of its parts may become wonderfully altered in form" (Huxley). To these detached reproductive portions of adult *Calycophoridæ* the term "Diphyozoöids" has been applied.

As regards the development of the *Calycophoridæ*, "not only the new polypites, but the new nectocalyces and reproductive organs, and even the branches of the tentacles, are developed on the proximal side of the old ones; so that the distal appendages are the oldest" (Huxley). The process of development is therefore the reverse of what obtains amongst the *Hydroida*.

Diphyes (fig. 55), which may be taken as the type of the *Calycophoridæ*, consists of a delicate filiform cœnosarc, provided proximally with two large mitre-shaped nectocalyces (v, v'), of which one lies entirely on the distal side of the other. The pointed apex of the distal nectocalyx is received into a special cavity in the proximal nectocalyx. The "hydrœcium" (h) is formed partially by this chamber in the nectocalyx, and partially by an arched groove prolonged upon the inner surface of the distal nectocalyx, within which the cœnosarc moves freely up and down, and can be entirely retracted if necessary. The upper part of the cœnosarc dilates into a small ciliated cavity, from which are given off two tubes, which proceed respectively to the distal and proximal nectocalyces, where they open into the central chamber from which the nectocalycine canals take their rise. The upper portion of this small ciliated cavity is prolonged proximally into the larger chamber of the "somatocyst." The cœnosarc (*c*) bears polypites, each of which is protected by a delicate glassy "hydrophyllium."

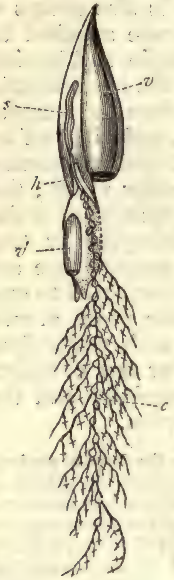

Fig. 55. — Calycophoridæ. *Diphyes appendiculata* (after Kölliker). *v* Proximal nectocalyx; *v′* Distal nectocalyx; *h* Hydrœcium; *c* Cœnosarc, carrying polypites each with its bract and tentacle.

ORDER II. PHYSOPHORIDÆ.—This second order of the *Oceanic Hydrozoa* comprises those *Siphonophora in which the hydrosoma consists of several polypites united by a flexible, contractile, unbranched or very slightly branched cœnosarc, the proximal extremity of which is modified into a "pneumatophore," and is sometimes provided with "nectocalyces." The polypites have either a single basal tentacle, or the tentacles arise directly from the cœnosarc. "Hydrophyllia" are commonly present. The reproductive bodies are developed upon gonoblastidia.*

The cœnosarc in the *Physophoridæ*, like that of the *Calycophoridæ*, is perfectly flexible and contractile; but it is not necessarily elongated, being sometimes spheroidal or discoidal. The proximal end of the cœnosarc "expands into a variously-shaped enlargement, whose walls consist of both ectoderm and endoderm, and which encloses a wide cavity in free communication with that of the cœnosarc, and, like it, full of the nutritive fluid. From the distal end, or apex, of this cavity depends a sac, variously shaped, but always with tough, strong, and elastic walls, composed of a substance which is stated to be similar to chitine in composition, and more or less completely filled with air" (Huxley). The large proximal dilatation of the cœnosarc is termed the "pneumatophore," whilst the chitinous air-sac which it contains is termed the "pneumatocyst" (fig. 54, 1). The pneumatocyst is held in position by the reflection of the endoderm of the pneumatophore over it, and it doubtless acts as a buoy or "float." In the Portuguese man-of-war (*Physalia*) the pneumatocyst communicates with the exterior by means of an aperture in the ectoderm of the pneumatophore. In *Velella* and *Porpita* the pneumatocyst communicates with the exterior by means of several similar openings called "stigmata;" and from its distal surface depend numerous slender processes containing air, and known as "pneumatic filaments."

The polypites of the *Physophoridæ* resemble those of the *Calycophoridæ* in shape, but the tentacles have a much more complicated structure, and are sometimes many inches in length, as in *Physalia*. The "hydrophyllia" have essentially the same structure as those of the former order. There occur also in the *Physophoridæ* certain peculiar bodies, termed "hydrocysts" or "feelers" ("fühler" and "taster" of the Germans). These resemble immature polypites in shape, consisting of a prolongation of both ectoderm and endoderm, usually with a tentacle, and containing a diverticulum of the somatic cavity, the distal extremity being closed, and furnished with numerous large thread-cells. They are looked upon as "organs of prehension and touch," and they are somewhat analogous to the "nematophores" of the Plumularians.

As regards the reproductive organs, they are developed upon special processes or "gonoblastidia," and they may remain permanently attached, or they may be thrown off as free-swimming medusoids. In many of the *Physophoridæ* the male and female gonophores differ from one another in form and size, and they are then termed respectively "androphores" and "gynophores." As regards their development, the *Physophoridæ* obey the same general law as the *Calycophoridæ*.

In *Physophora* the hydrosoma consists of a filiform cœnosarc, which bears the polypites and their appendages, and dilates proximally into a pneumatophore. Below this point the cœnosarc bears a double row of nectocalyces, which are channelled on their inner faces to allow of their attachment to the cœnosarc. There are no hydrophyllia, but there is a series of "hydrocysts" on the proximal side of the polypites.

Physalia, or the Portuguese man-of-war (fig. 56, *a*) is composed of a large, bladder-like, fusiform "float" or pneumatophore – sometimes from eight to nine inches in length—upon the under surface of which are arranged a number of polypites, together with highly contractile tentacles of great length, "hydrocysts," and reproductive organs. *Physalia* is of common occurrence, floating at the surface of tropical seas; and fleets of it are not uncommonly driven upon our own shores.

In *Velella* (fig. 56, *b*) the hydrosoma consists of a widely-expanded pneumatophore of a rhomboidal shape, carrying upon its upper surface a diagonal vertical crest. Both the horizontal disc and the vertical crest are composed of a soft marginal "limb," and a central more consistent "firm part." "To the distal surface of the firm part of the disc are attached the several appendages, including—1, a single large polypite, nearly central in position; 2, numerous small gonoblastidia, which resemble polypites, and are termed 'phyogemmaria;' and, 3, the reproductive bodies to which these last give rise. The tentacles are attached, quite independently of the polypites, in a single series along the line where the firm part and limb of the disc unite. There are no hydrocysts, nectocalyces, or hydrophyllia. . . . On all sides the limb is traversed by an anastomosing system of canals, which are ciliated, and communicate with the cavities of the phyogemmaria and large central polypite" (Greene). *Velella* is about two inches in length by one and a half in height. It is of a beautiful blue colour and semi-transparent, and it floats at the surface of the sea, with its vertical crest exposed to the wind as a sail.

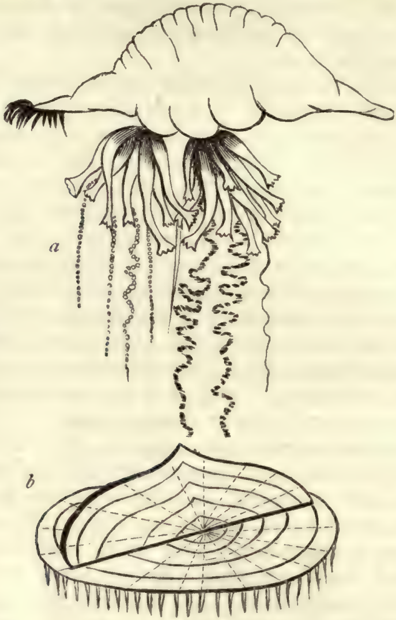

Fig. 56.—*Physophoridæ.* *a* Portuguese man-of-war (*Physalia utriculus*), showing the fusiform float and the polypites and tentacles (after Huxley); *b* *Velella vulgaris* (after Gosse).

CHAPTER X.

LUCERNARIDA, GRAPTOLITIDÆ, AND HYDROCORALLINÆ.

Sub-class IV. Lucernarida (*Acalephæ*, in part).—The members of this sub-class may be defined as *Hydrozoa* "*whose hydrosoma has its base developed into an* '*umbrella,*' *in the walls of which the reproductive organs are produced*" (Greene).

A large number of forms included in the *Lucernarida* were described by Edward Forbes under the name of *Steganophthalmate Medusæ*, being in many external characters closely similar to the *Medusidæ*. These "hidden-eyed" *Medusæ* are familiar to every one as "sea-blubbers" or "sea-jellies," and they occur in great numbers round our coasts during the summer months. The resemblance to the little jelly-fishes is especially strong between the disc or "nectocalyx" of the true *Medusidæ* and the "umbrella" of the *Lucernarida*, the latter being often a bell-shaped swimming organ, with marginal tentacles, and containing one or more polypites. These analogous structures (figs. 53 and 59) are, however, distinguished as follows: 1. The "umbrella" of the *Lucernarida* is never furnished with a "velum," as is the nectocalyx of the *Medusidæ*. 2. The radiating canals in the former are never less than eight in number, and they send off numerous anastomosing branches, which join to form an intricate network; whereas in the latter they are rarely more than four in number, and though they may subdivide, they do not anastomose. 3. In the place of the separate and unprotected "vesicles" and "ocelli" of the *Medusidæ*, the marginal bodies of the *Lucernarida* consist of these bodies combined together into single organs, which are termed "lithocysts," and which are protected externally by a sort of hood.

The *Lucernarida* admit of being divided into three orders—viz., the *Lucernariadæ*, the *Pelagidæ*, and the *Rhizostomidæ*.

Order I. Lucernariadæ.—This order includes those *Lucernarida which have only a single polypite, are fixed by a proximal hydrorhiza, and possess short tentacles on the margin of the umbrella. The reproductive elements* "*are developed in the primitive hydrosoma without the intervention of free zoöids*" (Greene).

In *Lucernaria* (fig. 57), which may be taken as the type of the order, the body is campanulate or cup-shaped, and is attached proximally at its smaller extremity by a hydrorhiza, which, however, like that of the *Hydra*, is not permanently fixed. When detached, the animal is able to swim with tolerable rapidity by means of the alternate contraction and expansion of the umbrella. Around the margin of the umbrella are tufts of short tentacular processes, and in its centre is a polypite with a quadrangular four-lobed mouth. "In transverse section the polypite may be described as somewhat quadrilateral, with a sinuous outline which expands at its four angles to form as many deep longitudinal folds, within which the simple generative bands are lodged" (Greene). Wide longitudinal canals are formed by septa passing from the walls of the polypite to the inner surface of the cup, and a circular canal runs immediately beneath the insertion of the tentacles. The reproductive elements are produced within the body of *Lucernaria* itself, without the intervention of any generative zoöid.

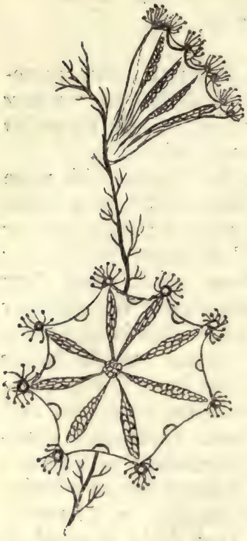

Fig. 57. — Lucernariadæ. *Lucernaria auricula* attached to a piece of sea-weed (after Johnston).

ORDER II. PELAGIDÆ.—This order is defined as including *Lucernarida which possess a single polypite only, and an umbrella with marginal tentacles. The reproductive elements "are developed in a free umbrella, which either constitutes the primitive hydrosoma, or is produced by fission from an attached Lucernaroid"* (Greene).

Two types, therefore, exist in the *Pelagidæ*. The one type is represented by a fixed "trophosome," resembling *Lucernaria*, but distinguished from it by the fact that the generative elements are not developed in the primitive hydrosoma, but in a free "gonosome," which is produced for the purpose. The second type, represented by *Pelagia* itself, is permanently free, thereby differing from *Lucernaria*, which it approaches, on the other hand, in the fact that its generative elements are produced in its own umbrella without the intervention of free generative zoöids. *Pelagia*, however, differs considerably in structure from *Lucernaria*, and in all essential characters is not anatomically separable from a *Steganophthalmate Medusid*. The process of reproduction as displayed in the first section of the *Pelagidæ* will be considered when treating of that of the

Rhizostomidæ, there being no important difference between the two, except as concerns the structure of the generative zoöids.

ORDER III. RHIZOSTOMIDÆ.—The members of this order are defined as being *Lucernarida* in which *the reproductive elements are developed in free zoöids, produced by fission from attached Lucernaroids. The umbrella of the generative zoöids is without marginal tentacles, and the polypites are "numerous, modified, forming with the genitalia a dendriform mass depending from the umbrella*" (Greene).

The following is a brief summary of the life-history of a member of this extraordinary order (fig. 58), the illustration, however, representing the development of *Aurelia*, one of the *Pelagidæ*, in which the phenomena are essentially the same. The embryo is a free-swimming, oblong, ciliated body, termed a "planula" (*a*), of a very minute size, and composed of an outer and inner layer, enclosing a central cavity. The planula soon becomes pear-shaped, and a depression is formed at its larger end. "Next, the narrower end attaches itself to some submarine body, whilst the depression at the opposite extremity, becoming deeper and deeper, at length communicates with the interior cavity. Thus a mouth is formed, around which may be seen four small protuberances, the rudiments of tentacula. In the interspaces of these four new tentacles arise; others in quick succession make their

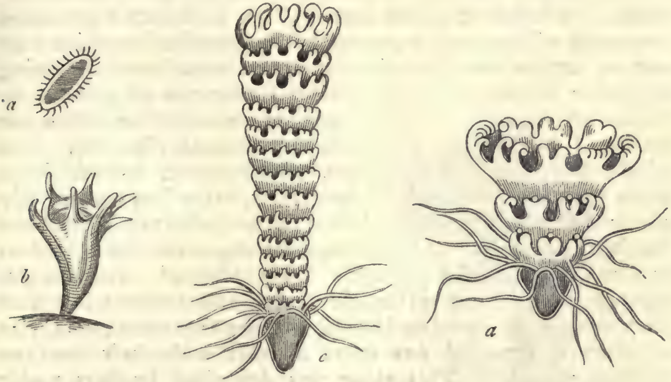

Fig. 58.—Development of *Aurelia*, one of the *Lucernarida*. *a* Ciliated free-swimming embryo, or "planula;" *b* Hydra-tuba; *c* Hydra-tuba in which fission has considerably advanced, and the "Strobila" stage has been reached; *d* Hydra-tuba in which the fission has proceeded still further, and a large number of the segments have been already detached to lead an independent existence.

appearance, until a circlet of numerous filiform appendages, containing thread-cells, surrounds the distal margin of the 'Hydra-tuba' (*b*), as the young organism at this stage of its career has been termed by Sir J. G. Dalyell. The mouth, in the meantime, from being a mere quadrilateral orifice, grows and lengthens itself so as to constitute a true polypite, occupying the axis of the inverted umbrella or disc, which supports the marginal tentacles. The space between the walls of the polypite and umbrella is divided into longitudinal canals, whose relations to the rest of the organism, and, indeed, the whole structure of *Hydra-tuba*, closely resemble what may be seen in *Lucernaria*" (Greene, 'Manual of Cœlenterata'). The *Hydra-tuba* thus constitutes the fixed "Lucernaroid," or the "trophosome" of one of the *Rhizostomidæ.* In height it is less than half an inch, but it possesses the power of forming, by gemmation, large colonies, which may remain in this condition for years, the organism itself being incapable of producing the essential elements of generation. Under certain circumstances, however, reproductive zoöids are produced by the following singular process (fig. 58). The *Hydra-tuba* becomes elongated, and becomes marked by a series of grooves or circular indentations, extending transversely across the body, from a little below the tentacles to a little above the fixed extremity. At this stage the organism was described as new by Sars, under the name "*Scyphistoma.*" The annulations or constrictions go on deepening and become lobed at their margin, till the *Scyphistoma* assumes the aspect of a pile of saucers, arranged one upon another with their concave surfaces upwards. This stage was described by Sars under the name of "*Strobila*" (*c*). The tentacular fringe which originally surrounded the margin of the *Hydra-tuba* now disappears, and a new circlet is developed below the annulations, at a point a little above the fixed extremity of the *Strobila* (*c*). "The disc-like segments above the tentacles gradually fall off, and, swimming freely by the contractions of the lobed margin which each presents, they have been described by Eschscholtz as true *Medusidæ* under the name of *Ephyræ* (*d*)." Each *Ephyra*, however, soon shows its true nature by becoming developed into a free-swimming reproductive body, usually of large size, with umbrella, hooded lithocysts, and tentacles, constituting, in fact, a *Steganophthalmate Medusa.* The reproductive zoöid now swims freely by the contraction of its umbrella, and it eats voraciously and increases largely in size. The essential elements of generation are then developed in special cavities in the umbrella, and the fertilised ova, when liberated, appear as free-swimming, ciliated "planulæ," which fix themselves, become *Hydra-tubæ*, and commence again the cycle of phenomena which we have above described.

As regards the *size* of these reproductive zoöids as compared with the organism by which they are given off, it may be mentioned that the umbrella of *Cyanea arctica* has been found in one specimen to be seven feet in diameter, with tentacles more than fifty feet in length, the fixed *Lucernaroid* from which it was produced not being more than half an inch in height.

As regards the special structure of these gigantic reproductive bodies, considerable differences obtain between the *Rhizostomidæ* and that section of the *Pelagidæ* in which this method of reproduction is employed. In the *Pelagidæ*, namely, the generative zoöids possess a general, though chiefly mimetic, resemblance both to the genuine *Medusidæ* and to the free-swimming medusiform gonophores of so many of the *Hydrozoa*, and they have the following structure. Each (fig. 59) consists of a bell-shaped, gelatinous disc, the "umbrella," from the roof of which is suspended a large polypite, the lips of which are extended into lobed processes often of considerable length, "the folds of which serve as temporary receptacles for the ova in the earlier stages of their development." The polypite—manubrium or proboscis—is hollowed into a digestive sac, which communicates with a cavity in the roof of the umbrella, from which arises a series of radiating canals, the so-called "chylaqueous canals." These canals, which are never less than eight in number, branch freely and anastomose as they pass towards the periphery of the umbrella, while the entire series is connected by a circular marginal canal. This, in turn, sends tubular processes into the marginal tentacles, which are

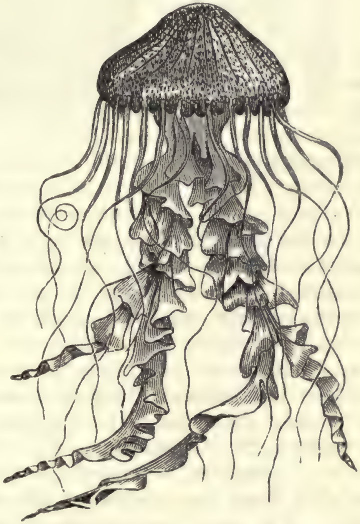

Fig. 59.—Hidden-eyed Medusæ. Generative zoöid of one of the *Pelagidæ* (*Chrysaora hyoscella*), after Gosse.

often of great length. Besides the tentacles, the margin of the umbrella is furnished with a series of peculiar bodies, termed "lithocysts," each of which is protected by a sort of process or hood derived from the ectoderm, and consists essentially of a combined "vesicle" and "pigment-spot," such as have been described as occurring separately in the *Medusidæ*. These marginal bodies likewise communicate with the chylaqueous canals. The reproductive elements "are lodged in saccular processes of the lower portion of the central cavity, immediately above the bases of the radiating canals, and being usually of some bright colour, form a conspicuous cross shining through the thickness of the disc" (Greene).

By a series of elaborate experiments, Mr G. J. Romanes has shown that the contractions of the swimming-bell of the Sea-blubbers obey the same laws as the contractions of muscular tissue generally, being excitable by the same stimuli, and similarly affected by chemical reagents. The removal of the margin of the umbrella causes a more or less total paralysis, and the same effect is produced by the excision of the marginal bodies, showing that these parts are the seat of the energy by which the movements are effected. Moreover, the severed margin of the swimming-bell continues to contract rhythmically for a considerable time after its complete separation from the organism itself. We are therefore justified in concluding that the margin of the swimming-bell contains what is functionally, if not structurally, a nervous system, though we have at present no direct anatomical evidence to demonstrate this.

In the *Rhizostomidæ* the reproductive zoöids (figs. 60, 61), differ from those we have just described as occuring in the first section of the *Pelagidæ*, in not possessing tentacles on the margin of the umbrella, and in having the simple central polypite replaced by a composite dendriform process, which bears numerous polypites, projects far below the umbrella, and is thus described by Professor Huxley: "In the *Rhizostomidæ* (figs. 60, 61), a complex, tree-like mass, whose branches, the 'stomatodendra,' end in, and are covered by, minute polypites, interspersed with clavate tentacula, is suspended from the middle of the umbrella in a very singular way. The main trunks of the dependent polypiferous tree, in fact, unite above into a thick, flat, quadrate disc, the 'syndendrium,' which is suspended by four stout pillars, the 'dendrostyles,' one springing from each angle, to four corresponding points on the under surface of the umbrella, equidistant from its centre. Under the middle of the umbrella, therefore, is a chamber, whose floor is formed by the quadrate disc, whilst its roof is constituted by the under wall of the central cavity of the umbrella, and its sides are open. The reproductive elements are developed within radiating folded diverticula of the root of this genital cavity." According to other authorities, however, the apparent polypites of the "stomatodendra" are really mouth-like apertures formed by the extraordinarily complex manner in which the oral lobes are folded, and there is then in reality but one single central polypite, hanging from the under surface of the umbrella.

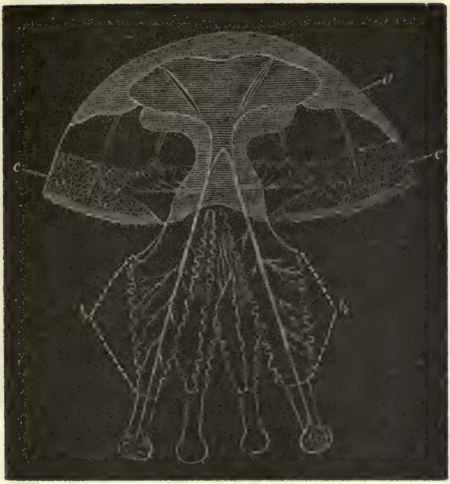

Fig. 60.—Rhizostomidæ. Generative zoöid of *Rhizostoma* (after Owen). *a* Umbrella; *bb* "Stomatodendra," covered with clavate tentacles and minute polypites; *c c* Anastomosing network of canals.

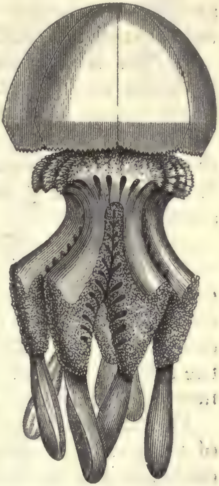

Fig. 61.—Generative zoöid of *Rhizostoma pulmo*, reduced in size. (After Gosse.)

It appears, finally, that amongst the old Pulmograde Acalephæ, or amongst what would commonly be called Jelly-fishes, we have the following distinct sets of beings, which resemble each other more or less closely in appearance, but differ in their true nature:—

1. Free medusiform gonophores of various *Corynida*, *Campanularida*, and the *Oceanic Hydrozoa*.

2. True *Medusidæ*, entirely resembling the former in anatomical structure, but differing in the fact that their ova do not give rise to a fixed zoöid, but to free-swimming organisms exactly like the parent hydrosoma (*Trachynemidæ*, *Geryonidæ*, and *Æginidæ*).

3. *Hydrozoa*, which are provided with an "umbrella" (with

all the peculiarities belonging to this structure), but which reproduce themselves without the intervention of free generative zoöids produced by fission (*Pelagia*).

4. The free generative zoöids of most of the *Pelagidæ*, with an umbrella and a single polypite, the primitive hydrosoma being fixed and sexless (*Aurelia*, *Cyanea*, &c.)

5. The free generative zoöids of the *Rhizostomidæ*, with an umbrella and a complex central tree bearing many polypites (*Rhizostoma*, *Cephea*, &c.)

Of these five classes of organisms, Nos. 1 and 2 constitute the Gymnophthalmate *Medusæ* of Professor E. Forbes, whilst Nos. 3, 4, and 5 are the Steganophthalmate *Medusæ* of the same naturalist.

SUB-CLASS V. GRAPTOLITIDÆ (= RHABDOPHORA, Allman).—The organisms included at present under this head are all extinct, and they are in many respects so dissimilar, and their structure is so far from being entirely understood, that it is doubtful if any definition can be framed which will include *all* the supposed members of the family. The following definition, however, will include all the most typical Graptolites :—

Hydrosoma compound, occasionally branched, consisting of numerous polypites united by a cœnosarc; the latter being enclosed in a strong tubular polypary, whilst the former were protected by hydrothecæ. In the great majority of Graptolites the hydrosoma was certainly unattached; but in some aberrant forms—doubtfully belonging to the sub-class—there is reason to believe that the hydrosoma was fixed. The polypites are never separated from the cœnosarc by any partition. In many cases the hydrosoma was strengthened by a chitinous rod, the "solid axis," somewhat analogous to the chitinous rod recently described by Professor Allman in the singular Polyzoön *Rhabdopleura*.

From the above definition it will be seen that the nearest living allies to the Graptolites are the Sertularians. In point of fact, if we do not insist upon the presence of a "solid axis" as part of the definition, the Graptolites differ from the Sertularians in no essential point, save that the hydrosoma is always attached in the latter, and was certainly free in the most typical examples of the former. Indeed, certain forms at present placed among the *Graptolites*—such as *Ptilograptus* and *Dendrograptus*—are so similar to some living Sertularians, that it might be well to remove them altogether from the *Graptolitidæ*, and to regard them as extinct representatives of the *Sertularida*.

As regards the value of the "solid axis" as an element in defining Graptolites, it is doubtful if much stress can be laid upon its presence or absence. It is true that it is present in all the most characteristic members of the sub-class, but it has not been proved to be present in some forms, which in other respects are quite typical members of the group.

Taking such a simple Graptolite as *G. priodon* (fig. 62) as the type of the sub-class, the hydrosoma is found to consist of the "solid axis," the "common canal," and the "cellules." The entire polypary is corneous and flexible, and the solid axis is a cylindrical fibrous rod, which gives support to the entire organism, and is often prolonged beyond one or both ends of the hydrosoma. There is, however, every reason for believing that the so-called "*solid* axis" is truly *hollow.* The common canal is a tube which encloses the cœnosarc, and gives origin to a series of cellules, these being little cups corresponding to "hydrothecæ," and enclosing the polypites. Not only are the essential details of the structure — with the exception of the solid axis—strictly comparable with that of a Sertularian, but there is good evidence that the reproductive process, in some forms at any rate, was also carried on in a manner similar to what we have seen in some other *Hydroida*—namely, by generative buds or gonophores enclosed in gonangia.

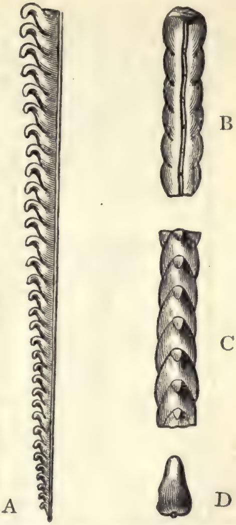

Fig. 62.—A, *Graptolites* (*Monograptus*) *priodon*, Bronn, preserved in relief — lateral view, slightly enlarged; B, Dorsal view of a fragment of the same species — considerably enlarged; C, Front view of a fragment of the same, showing the mouths of the cellules—much enlarged; D, Transverse section of the same. All from the base of the Coniston Flags. (Original.)

No *Graptolite*, however, has hitherto been certainly proved to have been fixed by a "hydrorhiza," and it is only in certain aberrant forms that there are any traces of a "hydrocaulus."

Besides the simple forms of Graptolites with a row of cellules on one side (monoprionidian) (fig. 62), there are others with a row of cellules on each side (diprionidian) (fig. 63). Many other modifications are known; but there is only another peculiarity which is worthy of notice here. This is the occurrence in several genera of a basal corneous disc or cup, which is probably the homologue of the "float" or "pneumatophore" of the Physophoridæ. (For distribution of Graptolites see Distribution of Hydrozoa in Time.

As regards their mode of occurrence, Graptolites are usually found as glistening, pyritous impressions, with a silvery lustre. In some cases, however, they are found in relief.

SUB-CLASS VI. HYDROCORALLINÆ.—This name has recently been proposed by Mr Moseley for two groups of marine animals which produce a regular skeleton of carbonate of lime, often of large size, and which have been generally referred to the Corals (*Actinozoa*). One of these groups comprises the well-known *Millepora* (fig. 64), which is found contributing so largely to the formation of coral-reefs in the West Indies and Pacific. The calcareous skeleton of *Millepora* is mostly in the form of foliaceous or laminar expansions, stony in texture, with a smooth surface studded with minute apertures of two sizes, the larger of these being much the fewest (fig. 64, C). The larger openings are the mouths of tubes (fig. 64, B, *p p*), which are divided by transverse calcareous partitions into a number of compartments, only the most superficial of these being actually tenanted by the living animal. The smaller tubes are similarly septate or "tabulate," and the general tissue of the skeleton (fig. 64, C) is composed of calcareous trabeculæ traversed by a series of ramifying and anastomosing cœnosarcal canals, which place the tubes occupied by the zoöids in direct communication.

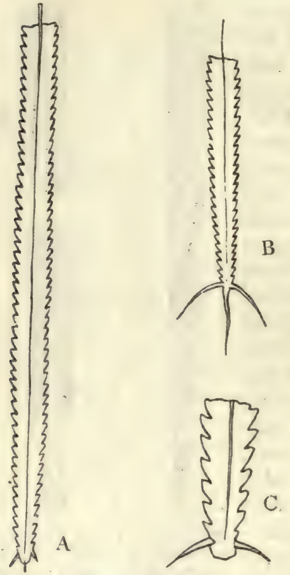

Fig. 63.—*Diplograptus pristis*, a diprionidian Graptolite. (Original.)

From the presence of transverse partitions, or "tabulæ," in its tubes, *Millepora* was generally placed amongst the so-called "Tabulate Corals," with the typical forms of which it has no affinity. Though its skeleton is abundantly obtained in the regions where it occurs, the living animal has been rarely observed. The late Professor Agassiz was the first to examine *Millepora* in its living condition, and he was led to the conclusion that the genus was unequivocally referable to the *Hydrozoa*. A similar conclusion has recently been reached by Mr Moseley, who had the opportunity of examining the living animal minutely. According to this observer, the colony (fig. 65) of *Millepora* consists of two kinds of zoöids. The larger zoöids, or "gastrozoöids," inhabit the larger tubes of the skeleton, and possess from four to six knobbed tentacles; while the smaller zoöids, or "dactylozoöids," inhabit the smaller tubes, and are either indiscriminately mixed with the gastrozoöids, or surround these in definite systems (fig. 65, *a* and *b*). The dactylozoöids have no mouth, and are long and slender, carrying on their sides numerous short clavate tentacles. They perform the functions of prehension for the colony, and supply food to the stomach-bearing gastrozoöids, by which the work of digestion and assimilation is carried on. The nutritive fluid elaborated by the latter is distributed throughout the entire colony by means of branched cœnosarcal canals, which ramify in every direction through the spongy tissue of the skeleton. The reproductive process in *Millepora* is still unknown.

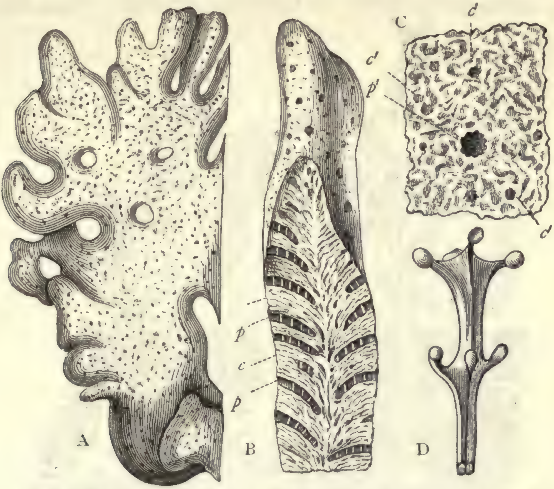

Fig. 64.—A, Portion of a mass of *Millepora alcicornis*, of the natural size; B, Portion of the same, cut open vertically to show the larger tabulate tubes (*p p*), and the spongy cœnosarcal skeleton (*c c*), enlarged; C, Small portion of the surface, enlarged to show the larger and smaller openings (*p'* and *c'*) inhabited by the different zoöids, and the reticulated calcareous tissue of the skeleton; D, One of the tentacular polypites, enlarged, showing two whorls of knobbed tentacles. (A, B, and C are after Milne-Edwards and Haime; D is after Martin Duncan and Major-General Nelson.)

Still more remarkable than the *Milleporæ* are the singular organisms forming the family of the *Stylasteridæ*, which have hitherto been regarded as Corals, but which have been shown by Mr Moseley to belong to the *Hydrocorallinæ*. The skeleton of the *Stylasteridæ* (fig. 66) is calcareous, more or less branched, forming a dendroid or flabellate expansion, and exhibiting upon the surface, or on its sides, small rounded apertures, which are usually intersected marginally by radiating partitions or "septa," and thus simulate the "calices" of an ordinary sclerodermic coral. In other cases, the skeleton shows a series of large apertures, with more numerous and irregularly distributed smaller openings, the latter not being radially ar-

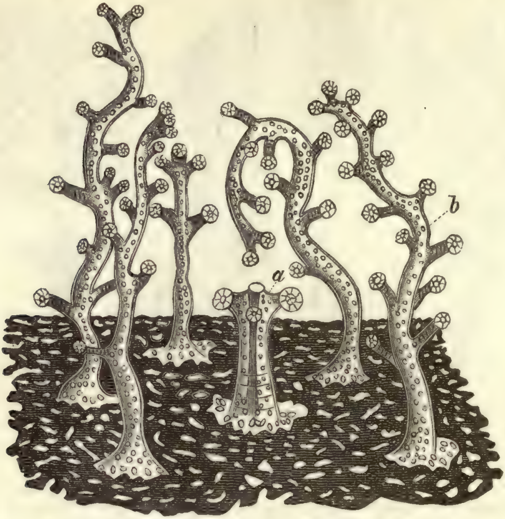

Fig. 65. — Enlarged view of a portion of the surface of a living colony of *Millepora nodosa*, showing the expanded zoöids of a single system: *a* Central "gastrozoöid;" *b* One of the mouthless "dactylozoöids." (After Moseley.)

ranged round the former. In any case, the skeleton is traversed in all directions by a system of branched and anastomosing canals, which are occupied in the living condition by prolongations of the cœnosarc, which also forms an ectodermal covering to the skeleton. The colony is composed of two different sets of zoöids—the one set ("gastrozoöids") provided with a mouth and stomach-sac; while the others ("dactylozoöids") are elongated and destitute of a mouth, thus coming to represent tentacles in form. The gastrozoöids occupy, as in *Millepora*, the large tubes of the skeleton, and the dactylozoöids, are lodged in the small tubes. Hence, when the dactylozoöids are arranged in definite "cyclo-systems" round the gastrozoöids, then each of the large apertures in the skeleton comes to be surrounded by a circle of smaller elongated pores, which are only separated laterally by thin partitions, and which thus give rise to the appearance of a central "calice" surrounded by radiated "septa" (fig. 66, B). The gastrozoöids are not only larger than the dactylozoöids, but they have a special layer of digestive cells lining the body-cavity, a structure which is wanting in the purely prehensile dactylozoöids. The true Hydrozoal character of these extraordinary organisms is conclusively shown by the fact that the reproductive organs are situated outside the bodies of the ordinary zoöids, being in the form of fixed sporosacs developed within sac-like cavities ("ampullæ") in the skeleton (fig. 66, B), which at certain periods communicate with the exterior by minute pores.

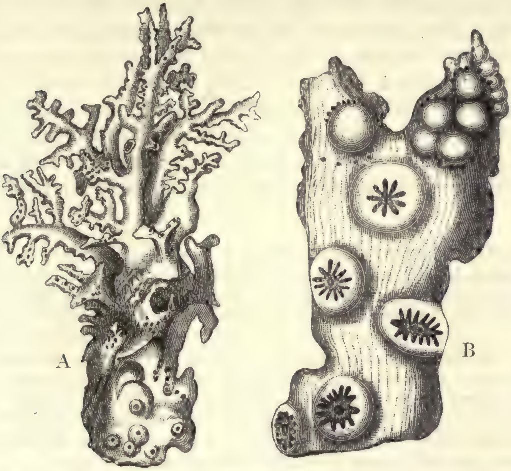

Fig. 66.—A, Portion of the skeleton of *Stylaster sanguineus*, of the natural size; B, Small portion of a branch of the same, enlarged, showing the calices and ampullæ. Living in the Australian Seas. (After Milne-Edwards and Haime.)

CHAPTER XI.

DISTRIBUTION OF THE HYDROZOA.

I. DISTRIBUTION OF HYDROZOA IN SPACE.—The genera of *Hydrozoa* have a wide distribution, the mode of reproduction amongst the fixed forms being such as to insure their extension over considerable areas. The various species of *Hydra* are of common occurrence in the fresh waters of various regions of the world. *Cordylophora*, the sole remaining fresh-water genus, has not been found to occur out of the north temperate zone. All the other *Hydrozoa*, without a known exception, are marine in their habits. The fixed forms—viz., the *Corynida*, *Sertularida*, and *Campanularida*—are represented more or less abundantly in almost all seas, extending from the littoral zone to considerable depths. The oceanic *Hydrozoa* (*Calycophoridæ* and *Physophoridæ*) are chiefly characteristic of tropical seas; but they are found also in the Mediterranean, and even in seas not far from, or even within, the arctic circle. Of the *Hydrocorallinæ*, *Millepora* is found in shallow water in the coral-reefs of the West Indies and Pacific Ocean, and the *Stylasterids* are almost cosmopolitan, the species ranging from the neighbourhood of the coast-line to great depths in the ocean.

II. DISTRIBUTION OF HYDROZOA IN TIME.—The fine-grained lithographic slates of Solenhofen and Eichstadt have yielded impressions of *Medusæ* belonging to the existing families of the *Æquoridæ* and *Trachynemidæ;* and the *Lucernarida* are represented by an ancient form of the *Rhizostomidæ* in the same formation. With these exceptions, however, there are few fossil remains which would universally be conceded to be of a *Hydrozoal* nature. The *Oldhamia* of the Cambrian rocks of Ireland has, indeed, been regarded as belonging to the *Hydrozoa;* but it is believed by Mr Salter to be really a plant. It consists of a main stem with numerous secondary branches, springing from the axis in an umbellate manner, but exhibiting no traces of hydrothecæ.

The occurrence of *Corynida* in a fossil condition, except in a few cases, can hardly be said to be free from doubt. Remains possibly referable to this order have been, however, recently discovered in the Palæozoic rocks. The oldest of these was described by the author some years ago from the Lower Silurian rocks of Dumfriesshire under the name of *Corynoides*. More lately a supposed Corynid called *Palæocoryne* has been described from the Carboniferous rocks of Scotland. Species of *Hydractinia* have also been described from the Cretaceous, Miocene, and Pliocene deposits.

The *Sertularida* and *Campanularida* are not certainly known to occur in a fossil condition. The fossils called *Dendrograptus*, *Callograptus*, *Ptilograptus*, and *Dictyonema*, all at present placed amongst the *Graptolites*, are, however, not improbably truly referable to the *Sertularida*.

There can be little doubt but that the large and singular family of the *Graptolitidæ* should really be looked upon as extinct *Hydrozoa*, though good authorities still place them amongst the *Polyzoa*. As regards their distribution two facts are chiefly noticeable. In the first place, no Graptolite, except the doubtful genus *Dictyonema*, has hitherto been found to occur above the Silurian rocks. The Graptolites may therefore be regarded as characteristic fossils of the Silurian period. Secondly, the diprionidian Graptolites, or those with a row of cellules on each side (*e.g.*, *Diplograptus* and *Climacograptus*), have in Bohemia alone been certainly shown to occur above the horizon of the *Lower* Silurian rocks. The common genus *Didymograptus* (comprising the "twin" Graptolites, fig. 67), is still more char-

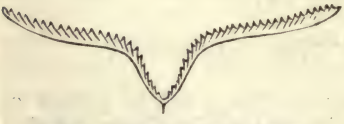
Fig. 67.—*Didymograptus V-fractus.*

acteristic of the Lower Silurian period. In *Didymograptus* the polypary consists of two lateral symmetrical branches, with cellules on one side only, springing from a central point or base, which is usually marked by a little spine or "radicle."

The *Hydrocorallinæ*, with the exception of some Cretaceous forms allied to *Millepora*, are not known to be represented in deposits older than the Tertiary.

CHAPTER XII.

ACTINOZOA.

1. General Characters of the Actinozoa. 2. Characters of the Zoantharia. 3. Zoantharia Malacodermata. 4. Zoantharia Sclerobasica. 5. Zoantharia Sclerodermata.

Class II. Actinozoa.—The *Actinozoa* are defined as *Cœlenterata with a differentiated digestive sac opening below into the somatic cavity, but separated from the body walls by an intervening "perivisceral space," which is divided into a series of compartments by vertical partitions or "mesenteries," to the faces of which the reproductive organs are attached.*

The *Actinozoa* (fig. 69), therefore, differ fundamentally from the *Hydrozoa* in this, that whereas in the latter the digestive cavity is identical with the somatic cavity, in the former there is a distinct digestive sac, which opens, indeed, into the somatic cavity, but is, nevertheless, separated from it by an intervening perivisceral space. As a result of this, the body of a typical *Actinozoön* (fig. 68) exhibits on transverse section two concentric tubes, one formed by the digestive sac, the other by the parietes of the body; whereas the transverse section of a *Hydrozoön* exhibits but a single tube, formed by the walls of the combined digestive and somatic cavity.

Histologically, the tissues of the *Actinozoa* are essentially the same as those of the *Hydrozoa*, consisting of the two fundamental layers, the "ectoderm" and the "endoderm." In the *Actinozoa*, however, there is a much greater tendency to a differentiation of these into specialised structures, and in some members of the class muscular fibres are well developed. Thus, the Sea-anemones have a well-developed series of longitudinal and circular muscular fibres, of which the former become radial in the disc and base. Cilia are often present, especially in the interior of the somatic cavity, where they serve to promote a circulation of the digestive fluids contained therein. The sole digestive apparatus in the *Actinozoa* consists of a tubular stomach-sac, which communicates freely with the outer world by means of the mouth, and opens inferiorly directly into the general body-cavity. In most, the "perivisceral space" between the body-walls and the digestive sac is subdivided into compartments by a series of vertical lamellæ, which are called the "mesenteries" (fig. 68, *m*). Upon the faces of these are borne the reproductive organs in the form of band-like ovaria or spermaria. There are no differentiated respiratory organs as a rule. Some forms, however, which live half buried in sand or mud, have lobed and crimped organs attached to or near the tentacles, which have been supposed to act as breathing-organs; whilst structures supposed to be gills are developed in some Zoanthids on either side of the primary mesenteries.

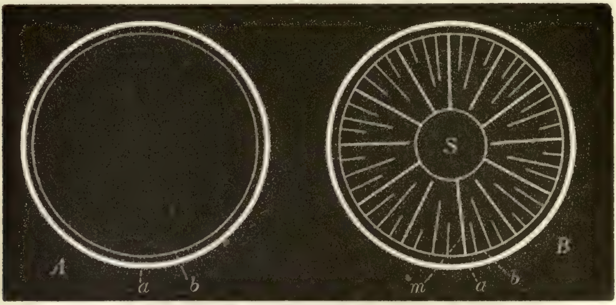

Fig. 68 —A, Transverse section of a *Hydrozoön*, showing the body-cavity in the form of a single tube enclosed by the body-walls. B, Transverse section of an *Actinozoön*: *s* Digestive sac; *m* One of the primary mesenteries, dividing the body-cavity into vertical compartments. Between the six primary mesenteries are seen the secondary and tertiary mesenteries, which fall short of the walls of the stomach. *a* Ectoderm; *b* Endoderm.

Thread-cells, often of very complicated structure, are almost universally present, some few forms having been asserted to be without them; and some of the *Actinozoa* are able to sting severely.

A nervous system has not yet been proved to exist in the *Actinozoa* generally, except in the *Ctenophora*, and in none are there any traces of a vascular system. Some *Actiniæ* are said to have short optic nerves distributed to the pigment-masses at the bases of the tentacles, and these masses are clearly of a sensory nature; whilst the same animals are affirmed to have a general nervous system as well.

Distinct reproductive organs occur in all the *Actinozoa*, but these are internal, and are never in the form of external processes as in the *Hydrozoa*. Sexual reproduction occurs in all the members of the class, but in many forms gemmation or fission constitutes an equally common mode of increase. Some *Actinozoa*, therefore, such as the common Sea-anemones, are simple organisms; whilst others, such as the reef-building corals, are composite, the act of gemmation or fission giving rise to colonies composed of numerous zoöids united by a cœnosarc. In these cases the separate zoöids are termed "polypes," the term "polypite" being restricted to the *Hydrozoa*. In the simple *Actinozoa*, however, the term "polype" is employed to designate the entire organism. In other words, the "actinosoma," or entire body of any *Actinozoön*, may be composed of a single "polype," or of several such, produced by a process of continuous gemmation or fission, and united by a common connecting structure, or cœnosarc.

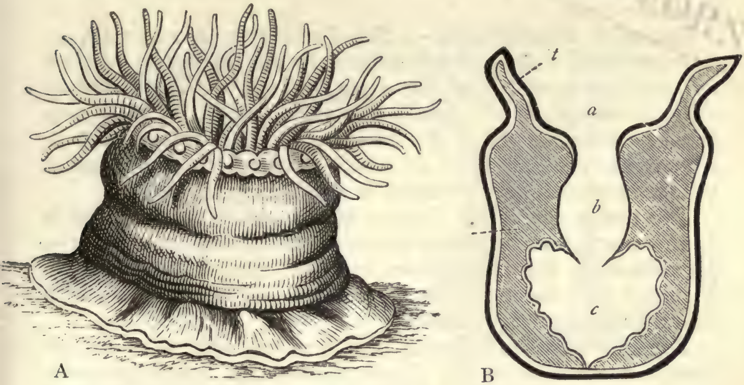

Fig. 69.—A, *Actinia mesembryanthemum*, one of the Sea-anemones (After Johnston); B, section of the same, showing the mouth (*a*), the stomach (*b*), and the body-cavity (*c*).

Most of the *Actinozoa* are permanently fixed; some, like the Sea-anemones, possess a small amount of locomotive power; and one order, the *Ctenophora*, is composed of highly active, free-swimming organisms. Some of the *Actinozoa* are unprovided with any hard structure or support, as in the Sea-anemones and in all the *Ctenophora;* but a large number secrete a calcareous or horny, or partially calcareous and partially horny, framework or skeleton, which is termed the "coral," or "corallum."

The *Actinozoa* are divided into four orders—viz., the *Zoantharia*, the *Alcyonaria*, the *Rugosa*, and the *Ctenophora;* but the last is sometimes placed amongst the *Hydrozoa*, and it has been recently proposed to remove the *Rugosa* also to the same class.

ORDER I. ZOANTHARIA. — The *Zoantharia*, *Hexacoralla*, or "Helianthoid Polypes," are defined *by the disposition of their soft parts in multiples of five or six, typically the latter, and by the possession of simple, usually numerous, tentacles. There may be no corallum, or rarely a "sclerobasic" one. Usually there is a "sclerodermic" corallum, in which the septa in each corallite, like the mesenteries, are arranged in multiples of five or six.*

The above characters, though distinctive of the *Zoantharia* as an order, are not capable of universal application, since the disposition of the mesenteries in sixes cannot be always recognised, and the tentacles are in rare instances fringed with lateral processes ("pinnate").

The *Zoantharia* are divided into three sub-orders—the *Zoantharia malacodermata*, the *Z. sclerobasica*, and the *Z. sclerodermata;* according as the corallum is entirely absent or very rudimentary, is "sclerobasic," or is "sclerodermic."

SUB-ORDER I. ZOANTHARIA MALACODERMATA.—In this section of the *Zoantharia* there is either no corallum or a pseudocorallum in the form of adventitious spicules scattered through the soft parts. The "actinosoma" is usually composed of but a single polype. (The term "actinosoma" is a very convenient one to express in the *Actinozoa* what "hydrosoma" expresses in the *Hydrozoa* — namely, the entire organism, whether simple or compound.)

There are three families in this section, of which the *Actinidæ* will require a somewhat detailed examination, since they may be taken as typical of the entire class of the *Actinozoa*.

FAMILY I. ACTINIDÆ.—The members of this family are commonly known as Sea-anemones, and are distinguished by having no corallum, or a spurious one, by being rarely compound, and by having the power of locomotion.

The body of a Sea-anemone (fig. 70, *a*) is a truncated cone, or a short cylinder, termed the "column," and is of a soft, leathery consistence. The two extremities of the column are termed respectively the "base" and the "disc," the former constituting the sucker, whereby the animal attaches itself at will, whilst the mouth is situated in the centre of the latter. Most Sea-anemones fix themselves by the base to some foreign object—a stone or a living animal—but others (*Peachia* and

Edwardsia) bury themselves more or less completely in the sand. In a few cases (*Cerianthus* and *Peachia*) the centre of the base is perforated, but the object of this arrangement is unknown. Some forms, again (*Minyas*, *Nautactis*, *Oceanactis*, &c.), are oceanic in their habit. Between the mouth and the circumference of the disc is a flat space, without appendages of any kind, termed the "peristomial space." Round the circumference of the disc are placed numerous tentacles, usually retractile, arranged in alternating rows, and amounting to as many as 200 in number in the common *Actinia*. The tentacles are tubular prolongations of the ectoderm and endoderm, containing diverticula from the somatic chambers, and often having apertures at their free extremities. The mouth leads directly into the stomach, which is a wide membranous tube, opening by a large aperture into the general body-cavity below, and extending about half-way between the mouth and the base. The wide space between the stomach and column-wall is subdivided into a number of compartments by radiating vertical lamellæ, termed the "primary mesenteries," arising on the one hand from the inner surface of the body-wall, and attached on the other to the external surface of the stomach. In reality the mesenteries are arranged in pairs, the chamber between each pair opening above into the cavity of a tentacle. As the stomach is considerably shorter than the column, it follows that the inner edges of the primary mesenteries below the stomach are free; and these free edges, curving at first outwards and then downwards and inwards, are ultimately

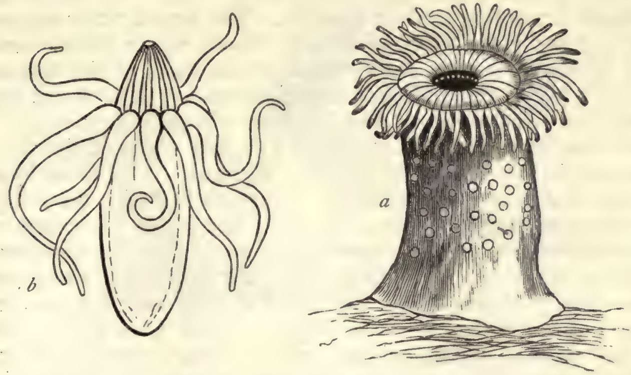

Fig. 70.—Morphology of Actinidæ. *a Actinia rosea*; *b Arachnactis albida*. (After Gosse.)

attached to the centre of the base. Besides the primary mesenteries, there are other lamellæ which also arise from the body-wall, but which do not reach so far as the outer surface of the stomach, and are called "secondary" and "tertiary" mesenteries, according to their breadth. The reproductive organs (fig. 35) are in the form of reddish bands, which contain ova and spermatozoa, and are situated on the faces of the mesenteries. Most of the *Actiniæ* are diœcious—that is to say, the same individual does not develop both ova and spermatozoa; but some forms are monœcious. The free edges of the mesenteries below the stomach are thickened, and constitute puckered and convoluted cords ("craspeda"), which are richly furnished with thread-cells. Attached also to the free edges of the mesenteries are sometimes found long thread-like filaments likewise crowded with thread-cells. These peculiar structures ("*acontia*") appear to be organs of offence and defence, as they can, on irritation, be rapidly shot forth from the mouth, as well as from certain minute orifices in the body-wall ("cinclides") which appear to be specially intended for their emission. As regards their nervous system, nerve-cells and anastomosing nerve-fibres are stated to be present in the base (Martin Duncan), and may exist in other parts of the Sea-anemones, whilst the pigment-masses at the bases of the tentacles in some forms appear undoubtedly to be rudimentary organs of vision.

The embryo of the *Actiniæ* is a free-swimming ciliated body, at first rounded, but afterwards somewhat ovate. The rudimentary mouth is soon marked out by a depression at the larger extremity; thread-cells appear as a layer in the ectoderm; a fold is prolonged inwards from the mouth to form the digestive sac; and the primitive tentacles are at first two in number, but are rapidly increased to six.

FAMILY II. ILYANTHIDÆ.—In this family there is no corallum, and the polypes are single and free, with a rounded or tapering base. *Ilyanthus* itself (fig. 71, B) is in all essential respects identical with the ordinary *Actiniæ*, but it is of a pointed or conical shape, the base being much attenuated, and it leads a free existence. *Arachnactis* (fig. 70, *b*) is also free, and according to Professor E. Forbes, it can not only swim like a jelly-fish, but "it can convert its posterior extremity into a suctorial disc, and fix itself to bodies in the manner of an *Actinia*." It is by no means certain, however, that *Arachnactis* is a mature form, and there is some reason to suppose that it is merely the young stage of some at present unknown *Actinozoön* (perhaps of *Edwardsia*).

Edwardsia (fig. 71, A) has a thin imperforate base, and lives buried to the lips in mud or sand, the middle of the body being protected by an epidermic investment. This curious form exhibits, as shown by Prof. Allman, many singular peculiarities of internal structure, amongst which the fact that the soft parts are in multiples of four may be specially noted. The distinguished authority just mentioned regards *Edwardsia* as in some respects intermediate between the *Zoantharia* and *Alcyonaria*, and as related to the extinct *Rugosa*. *Peachia* and *Cerianthus* also lived buried in the sand, both having the base perforated by an orifice, whilst the latter further protects itself by the secretion of a loose, membranous, non-adherent tube.

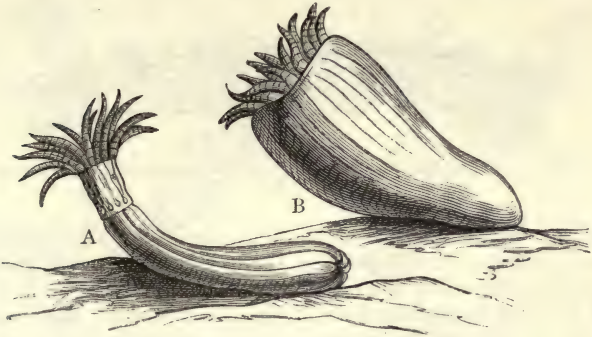

Fig. 71.—A, *Edwardsia callimorpha*; B, *Ilyanthus Mitchelli*, of the natural size. (After Gosse.)

FAMILY III. ZOANTHIDÆ.—The polypes in this family form colonies united by a fleshy or coriaceous cœnosarc, in the shape of a crust or of creeping roots, and they have no power of locomotion. The cœnosarc may be strengthened by embedded spicules, adventitious grains of sand, or other foreign bodies. Examples of the family are *Zoanthus* and *Palythoa*.

SUB-ORDER II. ZOANTHARIA SCLEROBASICA.—The "Black Corals" or *Antipathidæ*, which compose this group, are always *composite, consisting of a number of polypes united by a thin fleshy cœnosarc, which is spread over and supported by a simple or more commonly branched horny axis or "sclerobase." The tissues are not furnished with calcareous secretions, and the polypes have in general six simple tentacles.*

The corallum or skeleton of the *Antipathidæ* is of a horny consistence, its form simple or branched in a more or less complicated and plant-like manner, and its surface smooth or covered with minute spines. All the *Antipathidæ* form colonies, which are rooted by the base to some foreign object, and which consist of numerous minute polypes united by a fleshy cœnosarc (fig. 72). The corallum is secreted by the *cœnosarc*, and thus forms an *axis* or stem which is completely covered during life by the soft parts of the colony, just as the trunk of a tree is covered by the bark. Owing, further, to the fact that the skeleton is produced wholly by the cœnosarc, the corallum is wholly outside the polypes, which are themselves entirely destitute of hard structures. Various other *Actinozoa* (such as the *Gorgonidæ*) possess, as we shall see, a similar axial skeleton, secreted by the cœnosarc; and all such coralla are said to be "sclerobasic." As coralla of this nature are not formed by hard structures deposited within the tissues of the polypes, the general name of "foot-secretion" has been applied to them by Prof. Dana.

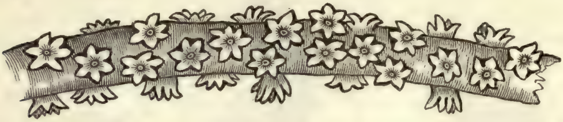

Fig. 72.—Part of the living stem of *Antipathes anguina*, of the natural size. (After Dana.)

SUB-ORDER III. ZOANTHARIA SCLERODERMATA OR MADREPORARIA.—The members of this sub-order include the great bulk of coral-producing or "coralligenous" zoophytes (*Madreporaria*) of recent seas. They are defined by the possession of *a corallum which is partially or wholly developed within the tissues of the polypes themselves* ("*sclerodermic*"), *which does not consist simply of scattered spicules, and in which the parts are very generally disposed in multiples of six. The actinosoma may be simple, consisting of a single polype only, or composite, consisting of many polypes united by a cœnosarc.*

As regards the anatomy of their soft parts, the simple *Zoantharia sclerodermata* may be regarded as essentially Sea-anemones, whilst the compound forms are simply colonies of Actinoid polypes united by a common flesh or cœnosarc. It is, therefore, only necessary to consider the nature of the skeleton or corallum of these forms, since the leading peculiarities of the sub-order are to be found in this.

If we examine first a simple coral of this group, we find that we have to deal with an animal in all important respects identical with an ordinary Sea-anemone, but having a more or less complicated skeleton developed in its interior. The animal possesses a base, a column, and a disc—the latter surrounded by tentacles, and perforated centrally by the mouth. The mouth opens into a stomach-sac, connected with the body-walls by mesenteries; and the tentaculate disc and dependent gastric sac remain permanently soft and capable of contraction and expansion. Below the stomach, the soft tissues of the polype are strengthened and supported by a more or less perfect calcareous skeleton or corallum (fig. 74). This is composed of calcareous matter ("sclerenchyma") deposited by and in the tissues themselves, between the endoderm and ectoderm, and the corallum is thus *within the polype*, and is technically said to be "sclerodermic." The "sclerodermic" corallum is therefore a true "tissue-secretion," and thus differs conspicuously from the "sclerobasis" of the *Antipathidæ* and *Gorgonidæ*, which is secreted by the cœnosarc, and is not formed by a calcification of the soft parts of the polypes themselves. The general distinction, arising from their mode of formation, between "sclerobasic" and "sclerodermic" corals, is not, perhaps, of essential importance, and the boundary-line between the two is not very clearly marked; but it is of considerable practical value. It is, moreover, a distinction which is readily recognised, as a rule, by a simple inspection of the corallum itself. A sclerobasic corallum, namely, being secreted solely by the cœnosarc, never exhibits any parts which correspond

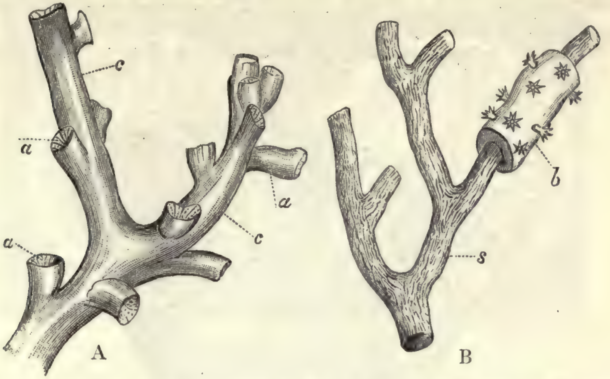

Fig. 73.—Sclerodermic and sclerobasic Corals. A, Branch of *Dendrophyllia nigrescens*, a sclerodermic coral, showing the cups or thecæ (*a a*) secreted by the separate polypes, and united by the cœnenchyma (*c c*). B, Portion of a sclerobasic coral (*Gorgonia*) represented diagrammatically: *s* The solid and branched sclerobase; *b* A portion of the soft cœnosarc with its embedded polypes, investing the sclerobasic axis.

with the separate polypes of the colony. On the other hand, the sclerodermic corallum (when not composed simply of scattered spicules) either consists of a single cup-like structure corresponding with a single polype (fig. 74), or of several such (fig. 73, A) united by a common skeleton.

A typical simple sclerodermic corallum (fig. 74) is secreted by a single polype, and its structure presents an obvious correspondence with that of the animal which produces it. It is generally more or less conical in shape, sometimes discoid, consisting of an outer wall and included space. The wall is secreted by the mesoderm of the column and base, and is known as the "theca." It may be very imperfect, or may be strengthened by a secondary calcareous investment ("epitheca.") The theca encloses a space which corresponds with the lower part of the body-cavity of the polype, and is known as the "visceral chamber." Superiorly the theca terminates in a shallower or deeper cup-shaped depression, which contains the stomach-sac of the polype, and is known as the "calice." Below the calice, the visceral chamber is subdivided into a number of vertical compartments ("loculi") by a series of upright partitions or "septa," which spring from the inner surface of the theca, and are directed inwards towards the centre. The septa are calcifications formed within the me-

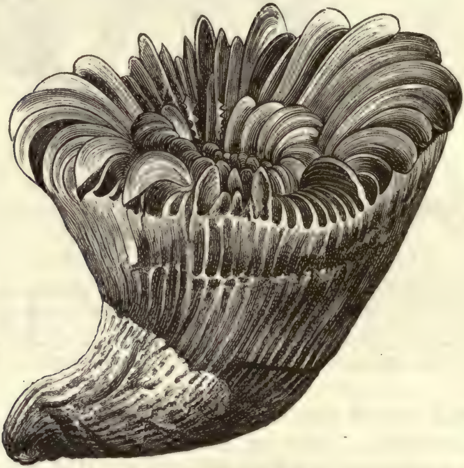

Fig 74.—*Caryophyllia borealis.* A simple sclerodermic Coral, twice the natural size. (After Sir Wyville Thomson.)

senteries, to which, therefore, they correspond in number and size. Like the mesenteries, the septa are thus "primary," "secondary," and "tertiary," according to their width (fig. 75).

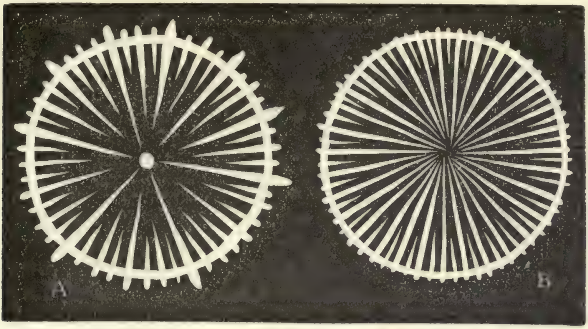

Fig. 75.—Diagram of the arrangement of the septa in the *Zoantharia sclerodermata* and *Rugosa.* A, Transverse section of a simple sclerodermic Coral (*Turbinolia*), showing the theca, with its projecting ridges or "costæ" outside, the visceral chamber and radiating septa inside, and the columella in the centre. B, Transverse section of a simple Rugose Coral (*Cyathophyllum*), showing the wall, costæ, and septa.

The septa in the adult sclerodermic corallum are typically some multiple of six in number, arranged in six systems; but this rule is not of universal application, and the typical hexameral arrangement may be departed from altogether. The laws of development of the septa are complicated, and need not be discussed here. On the outside of the theca are vertical ridges ("costæ"), corresponding with the septa within; and the centre of the visceral chamber may be vacant, or may be occupied by an axial rod-like structure, which is termed the "columella." The continuity of the "interseptal loculi" is liable to be more or less interfered with by the development of the structures known as "*synapticulæ*," "dissepiments," and "tabulæ." The "synapticulæ" are transverse calcareous bars which stretch across the interseptal loculi, and form a kind of trellis-work, uniting the opposite faces of adjacent septa. They are characteristic of the *Fungidæ.* The "dissepiments" are commonly present in a great many corals, and have the form of incomplete, approximately horizontal plates, which stretch between adjacent septa, and break up the interseptal loculi into secondary compartments or cells. Lastly, the "tabulæ" may be regarded as highly developed dissepiments, and, like them, are approximately horizontal, as a rule, at any rate. They differ from the dissepiments in the fact that they cut across the interseptal loculi at the same level. When fully developed (fig. 76, D), they are transverse plates, which extend completely across the visceral chamber, and divide it into a series of storeys placed one above the other, the only living portion of the coral being above the last-formed tabula. Tabulæ are found in various of the *Zoantharia sclerodermata*, in some of the *Alcyonaria*, and in a great many of the *Rugosa*.

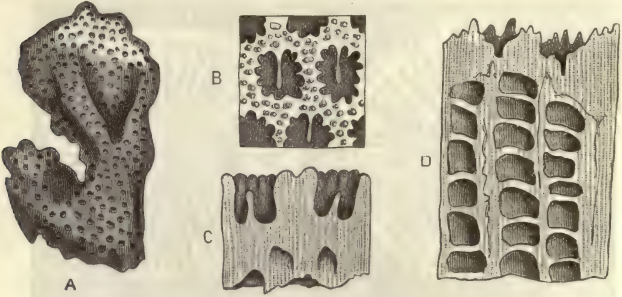

Fig. 76.—A, Portion of the corallum of *Pocillopora aspera*, var. *lata*, Verrill, of the natural size. B, Part of the surface of same, enlarged. C, Section of the corallites of the same, showing the columella, enlarged. D, Vertical section of the same, enlarged, showing tabulæ. (After Dana.)

The above gives the general structure of a typical simple sclerodermic corallum, as secreted by a single polype. A *compound* sclerodermic corallum is the aggregate skeleton produced by a colony of such polypes, and varies in form and size according to the characters of the colony by which it is produced. In general, such a colony consists (fig. 77) of a number of polypes, which may spring directly from one another, or may be united by a common flesh or cœnosarc; and corresponding elements are found in the corallum. In the former instance, the compound corallum consists of an assemblage of separate "corallites," as the skeletons of the individual polypes are called, these being united with one another directly and in various ways. In the latter instance, the corallum consists of a number of "corallites," and of a common calcareous basis or tissue, which unites the various corallites into a whole, is secreted by the cœnosarc, and is known as the "cœnenchyma."

The compound coralla are, of course, primitively simple, and they become composite either by budding or by cleavage of the original polype. The following are the principal methods in which this increase is effected; and in considering this subject briefly, it will be as well to take into account not only the *Zoantharia sclerodermata*, but also the *Rugosa*, the modes of increase in the two groups being very similar: (1.) *Lateral* or *parietal* *gemmation.*—In this mode of increase the original polype throws out buds from some point on its sides between the base and the circle of tentacles, and these buds on becoming perfect corallites may repeat the process. This is one of the commonest modes of growth amongst the recent corals, and it gives rise chiefly to dendroid or tree-like corals.

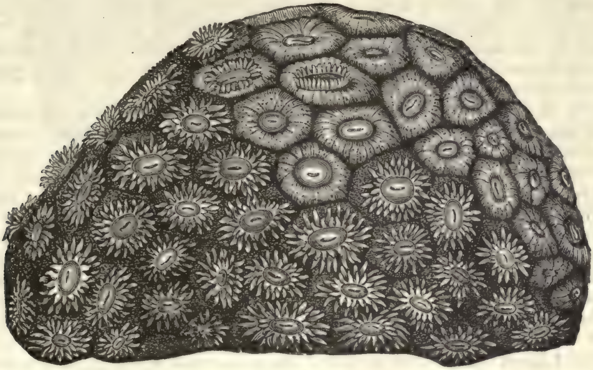

Fig. 77.—*Astræa pallida*, a compound sclerodermic Coral, in its living condition. (After Dana.)

(2.) *Basal gemmation.*—In this method the original polype gives forth from its base a rudimentary cœnosarc, from which new buds are thrown up, and which may have the form of foot-like prolongations or of a continuous horizontal expansion. The resulting coralla are usually massive or encrusting, and the youngest corallites are, of course, those placed on the periphery of the colony.

(3.) *Calicular gemmation.*—This consists in the production of buds from the calicine disc of the parent corallite, which may or may not continue to grow thereafter, whilst the new corallites thus produced generally repeat the process. This mode of growth is exceedingly rare amongst the *Zoantharia sclerodermata*, and is never typically exhibited; but it is a characteristic feature in many of the *Rugose* corals. In many of these (fig. 78), the original polype throws up from its calicine disc one or more new corallites, which kill the parent. These, in turn, produce others after a similar fashion, till the entire corallum assumes the form of an inverted pyramidal mass resting upon the original budding polype. In other *Rugose* corals the calicine disc gives off but a single bud, which may repeat the process indefinitely till the corallum presents the appearance of a succession of inverted cones placed one above the other.

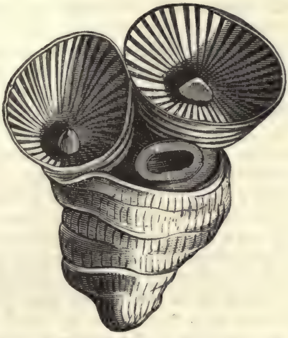

Fig. 78.—Calicular gemmation as seen in *Lonsdaleia floriformis*. Carboniferous.

(4.) *Fission.*—This process in the coralligenous *Actinozoa* is usually effected by "oral cleavage," the divisional groove commencing at the oral disc, and deepening to a greater or less extent, the proximal extremity always remaining undivided. According to Dana, in fission a new mouth is formed in the disc near the old mouth, and a new stomach is formed for the new mouth, round which the new tentacles are then developed. This, therefore, is not, strictly speaking, a subdivision into halves; since one half carries off the old mouth and stomach. More rarely, fission "is effected by the separation of small portions from the attached base of the primitive organism, whose form and structure they subsequently, by gradual development, tend to assume."

"The coral-structures which result from a repetition of the fissiparous process are of two principal kinds, according as they tend most to increase in a *vertical* or in a *horizontal* direction. In the first of these cases the corallum is *cæspitose*, or tufted, convex on its distal aspect, and resolvable into a succession of short diverging pairs of branches, each resulting from the division of a single corallite." In the second case the coral becomes *lamellar.* "Here the secondary corallites are united throughout their whole height, and disposed in a linear series, the entire mass presenting one continuous theca." Both these forms of corallum are "liable to become *massive* by the union of several rows or tufts of corallites throughout the whole or a portion of their height. An illustration of this is afforded by the large *gyrate* corallum of *Meandrina*, over the surface of whose spheroidal mass the calicine region of the combined corallites winds in so complex a manner as at once to suggest that resemblance to the convolutions of the brain which its popular name of Brain-stone Coral has been devised to indicate" (Greene).

The *Zoantharia sclerodermata* are divided into the two following groups, founded upon the characters of the corallum :—

1. *Aporosa.*—The calcareous tissue of the corallum is more or less compact and imperforate; the septa usually constituting complete solid plates, and the theca being as a rule not pierced by any apertures. Dissepiments or synapticulæ are usually present, but tabulæ are rarely developed. This section includes the most highly developed of existing corals (*Turbinolidæ*, *Oculinidæ*, *Astræidæ*, *Fungidæ*, &c.)

2. *Perforata.*—The calcareous tissue of the corallum is more or less porous, loosely aggregated, spongy, or reticulate, the walls in all being perforated with more or fewer apertures. The septa are generally well developed, but they are also perforated by apertures, and may be simply trabecular. Imperfect dissepiments may be present, and in some cases there are well-developed tabulæ; but the visceral chamber is usually more or less completely open from top to bottom. The three families comprised in this section are the *Eupsammidæ*, the *Madreporidæ*, and the *Poritidæ*, to which must be added the great and almost extinct family of the *Favositidæ.*

In addition to the above-mentioned groups of the *Zoantharia sclerodermata* two other groups have been established under the names of the *Tabulata* and *Tubulosa.* The former of these included the so-called "Tabulate Corals," distinguished by the imperfect development of the septa, and the fact that the visceral chamber is divided into compartments by horizontal plates or "tabulæ" (fig. 76, D). Some of the so-called "Tabulate Corals," however, such as *Millepora*, have been shown to be *Hydrozoa;* others, such as *Pocillopora* (fig. 76) belong to the Aporose division of the *Zoantharia sclerodermata;* others, again, such as *Favosites* and its allies (fig. 79), belong to the Perforate division of the *Z. sclerodermata*, and are very nearly related to the *Poritidæ;* others are referable to the *Alcyonaria;* while others, lastly, are of uncertain affinities. It is clear, therefore, that the section *Tabulata* can no longer be retained as a division of the *Zoantharia sclerodermata*, or as a division of the Corals of any zoological value. The section *Tubulosa* (including only the Palæozoic genera *Aulopora* and *Cladochonus* or *Pyrgia*) is also of no zoological value, in the present state of our knowledge. The forms included in it are simple or compound, with trumpet-shaped thecæ, rudimentary septa, and few or imperfect tabulæ; and they are probably referable to the *Alcyonaria.*

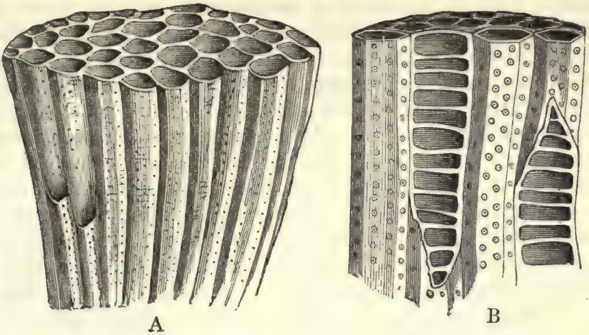

Fig. 79.—A, Portion of the corallum of *Favosites favosa,* of the natural size. B, Portion of four corallites of *Favosites Gothlandica,* enlarged, showing the tabulæ and the "mural pores" or openings in the walls of the corallites.

CHAPTER XIII.

ALCYONARIA.

ORDER II. ALCYONARIA.—The second great division of living *Actinozoa* is that of the *Alcyonaria*, defined by the possession of *polypes with eight pinnately-fringed tentacles, the mesenteries and somatic chambers being also a multiple of four* (*eight*). *The corallum, when present, is usually sclerobasic, or spicular; if "thecæ" are present, as is rarely the case, septa are wanting or rudimentary.*

The *Alcyonaria* or "Asteroid Polypes" differ numerically from the *Zoantharia* in having their soft parts arranged in multiples of *four*, instead of *five* or *six*, as in the latter, whilst the septa are not in pairs. Their tentacles, too, are pinnate, and are not simply rounded. Numerically, the *Alcyonaria* agree with the extinct order *Rugosa;* but the latter invariably possess a well-developed sclerodermic corallum, the thecæ of which exhibit either septa or tabulæ, or both combined.

With the exception of two genera (*Haimeia* and *Hartea*), both of which are possibly founded upon immature forms, the *Alcyonaria* are all composite, the tubular polypes being united by a cœnosarc, and their body-cavities being placed in communication by means of anastomosing canals, which ramify in the cœnosarc, and permit of a free circulation of nutrient fluids. The form of the colony differs greatly in different cases, but none possess the power of independent locomotion, most being rooted to foreign objects, or sunk in the mud, whilst some float freely in the sea. The polypes, in most of the essential points of their organisation, agree with those of the *Zoantharia*, the mouth opening into a tubular stomach, which in turn communicates freely with the body-cavity, and the stomach-sac being connected with the body-wall by means of a series of vertical membranous laminæ or "mesenteries." The mesenteries, however, are only eight in number, and are not paired, one of the tentacles corresponding with and opening into each intermesenteric chamber. A corallum may be wanting, and when present its structure varies. In some cases, lastly, it has been shown that the actinosoma normally consists of two kinds of polypes—one sexual, the other sexless and permanently rudimentary. The *Alcyonaria* are divided into five families—viz., the *Alcyonidæ*, the *Tubiporidæ*, the *Pennatulidæ*, the *Gorgonidæ*, and the *Helioporidæ*.

FAMILY I. ALCYONIDÆ.—This family is characterised by the possession of *a fixed actinosoma, which is provided with a sclerodermic corallum in the form of calcareous spicula embedded in the tissues.* The spicules are mostly fusiform in shape, and are generally present both in the polypes themselves and in the connecting cœnosarc; but there is no central solid axis.

Alcyonium may be taken as the type of the family, and it is well known to fishermen under the name of "Dead-men's fingers." It forms spongy-looking, orange-coloured crusts or lobate masses, which are attached to submarine objects, and are covered with little stellate apertures, through which the delicate polypes can be protruded and retracted at will. The polypes communicate with one another by an anastomosing system of aquiferous tubes, and the corallum is in the form of cruciform, calcareous spicula scattered through its substance. In the allied *Sarcodictyon* the actinosoma is creeping and linear.

In *Xenia* the colony is branched, and the polypes are non-retractile; and in *Anthelia* and *Sympodium* the actinosoma has the form of a membranous crust attached to foreign bodies. Lastly, in *Sarcophyton* (as shown by Moseley) the colony consists of reproductive zoöids, which have generative organs and tentacles, and of sexless zoöids, which have neither of these organs, but possess a mouth and stomach-sac.

FAMILY II. TUBIPORIDÆ.—In the *Tubiporidæ*, or "organ-pipe corals," of which *T. musica* (fig. 80) is a familiar example, there is *a well-developed sclerodermic corallum, with thecæ, but without septa.* The corallum is composed of a number of bright-red, tubular, cylindrical thecæ, which are united together externally by horizontal plates or floors, which appear to be formed by periodical extensions from the mouths of the tubes. The polypes are usually bright green in colour, and possess eight tentacles each.

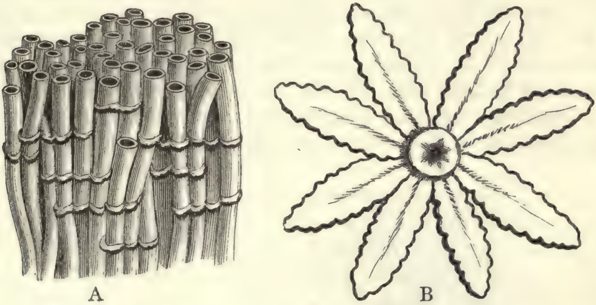

Fig. 80.—A, Portion of the corallum of *Tubipora musica*, of the natural size, showing the tubular corallites and their connecting floors. B, Polype of the same, greatly enlarged, showing the mouth and tentacles.

As shown by Prof. Perceval Wright, the tubes of *Tubipora* are in reality composed of fused spicules; and the polypes when alarmed retract themselves within their tubes, the upper portions of which are composed of loose fusiform spicules, and are thus capable of withdrawal into the lower dense portion of the thecæ.

FAMILY III. PENNATULIDÆ.—The *Pennatulidæ*, or "Sea-pens," are defined by their *free* habit, and by the possession of *a sclerobasic, rod-like corallum, sometimes associated with sclerodermic spicules.*

Pennatula, or the "Cock's-comb," consists of a free cœnosarc, the upper end of which is fringed on both sides with feather-like lateral pinnæ, which bear the polypes; whilst its proximal end is smooth and fleshy, and is probably sunk in the mud of the sea-bottom. This latter portion of the cœnosarc is likewise strengthened by a long, slender, styliform sclerobasis, resembling a rod in shape, whilst spicula occur also in the tentacles and ectoderm. The general colour of *Pennatula* is a deep reddish purple, the proximal extremity of the cœnosarc being orange-yellow. The common British species (*Pennatula phosphorea*) varies from two to four inches in length, and is found on muddy bottoms in tolerably deep water. Its specific name is derived from the fact that it phosphoresces brilliantly when irritated.

In *Virgularia* (fig. 82), which, like *Pennatula*, occurs not uncommonly in British seas, the actinosoma is much longer and more slender than in the preceding, and the polype-bearing fringes are short. The polypes have eight tentacles. The sclerobasis is in the form of a long calcareous rod, like a knitting-needle, and part of it is usually naked. No spicula are found in the tissues of *Virgularia*. In the nearly-allied *Pavonaria* the polype-mass is quadrangular in shape.

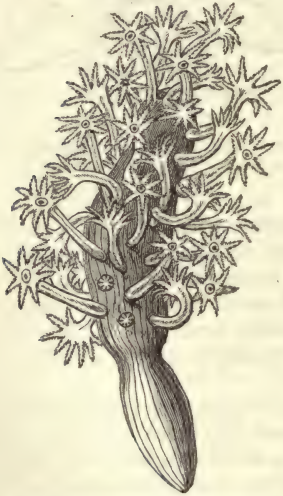

Fig. 81.—Colony of *Veretillum cynomorium*, of the natural size, with the polypes protruded.

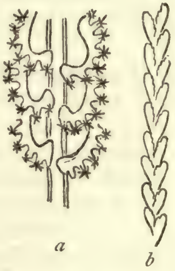

Fig. 82. — Pennatulidæ. *Virgularia mirabilis*. *a* A portion of the stem in the living condition, enlarged; *b* Portion of the stem in its dead condition.

In *Veretillum* (fig. 81), the upper portion of the colony is short and club-shaped, and carries the polypes all round its circumference, and the same is the case in *Cophobelemnon;*

whilst in *Renilla* the polypes are unilateral, and the polypiferous cœnosarc is thin and reniform.

In many of the *Pennatulidæ*, as originally shown by Kölliker, the actinosoma consists of two classes of zoöids—the one composed of sexually mature polypes, the other, more numerous, of sexless polypes—which have a body-cavity and stomach, but have neither mouth nor tentacles. These sexless zoöids may be distributed promiscuously over the whole actinosoma (*Veretillum*, &c.), or they may be restricted to definite regions (*Pennatula*, *Virgularia*). Whilst many of the *Pennatulidæ* seem to live habitually sunk partially in the mud of the sea-bottom, others are found freely floating in the water, and their mode of life is not completely understood.

FAMILY IV. GORGONIDÆ.—In the *Gorgonidæ*, or "Sea-shrubs," there is *an arborescent cœnosarc permanently rooted and provided with a grooved, or sulcate, branched sclerobasis, associated with true tissue-secretions, termed "dermosclerites.*

The sclerobasis of the *Gorgonidæ* varies a good deal in its composition. In some it is corneous, and these have often been confounded with the *Antipathidæ*, amongst the *Zoantharia.* The distinction, however, between them is easy, when it is remembered that the polypes in the *Gorgonidæ* have tentacles in multiples of *four*, whilst in the *Antipathidæ* they are in *sixes.* The sclerobasis, too, in the former is always marked by grooves, whereas in the latter it is always either smooth or spinulous. In *Isis* and *Mopsea* the sclerobasis consists of alternate calcareous and horny segments, branches being developed in the former from the calcareous, and in the latter from the horny segments.

In *Corallium rubrum*, the "red coral" of commerce (fig. 83), the sclerobasis is unarticulate, or unjointed, and is entirely calcareous. It is the most familiar member of the family, and is largely imported for ornamental purposes. Red coral consists of a branched, densely calcareous sclerobasis, which is finely grooved upon its surface, is of a bright-red colour, and is in reality composed of fused spicules. The corallum is invested by a cœnosarc, also of a red colour, which is studded by the apertures for the polypes, which are white, and possess eight pinnately-fringed tentacles. The entire cœnosarc is channelled out by a number of anastomosing canals, which communicate with the somatic cavities of the polypes, and are said to be in direct communication with the external medium by means of numerous perforations in their walls. The entire canal system is filled with a nutrient fluid, containing corpuscles, and known as the "milk."

In the typical *Gorgoniæ* the sclerobasis is horny, and more or less arborescent, and the same is the case in the "Fan Corals" (*Rhipidogorgia*), in which the corallum has the form of a regularly reticulate fan-shaped expansion. The soft tissues of the *Gorgonidæ* are abundantly supplied with sclerodermic secretions in the form of calcareous spicules of very various shapes, and often of very brilliant colours, which are in many instances of such characteristic figures that they can be employed as a ground of generic distinction. These spicules ("sclerites") are very generally buried in the soft tissues, but they may project beyond the surface of the cœnosarc in such numbers as to render the integument rough and prickly.

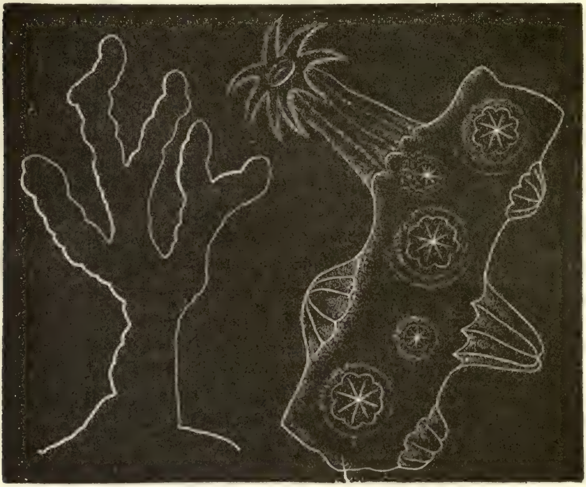

Fig. 83.—Red Coral (*Corallium rubrum*) of the natural size, and a portion enlarged.

FAMILY V. HELIOPORIDÆ.—The Alcyonarians of this group possess *a well-developed sclerodermic corallum, composed of tabulate tubes of two sizes, the larger ones being furnished with rudimentary septal laminæ.*

The family *Helioporidæ* has been recently founded by Mr Moseley for the reception of the living *Heliopora cærulea* (fig. 84), and of a number of extinct corals previously placed in the "Tabulate" section of the *Zoantharia sclerodermata.* In *Heliopora* the corallum is composite and sclerodermic, and composed of corallites united by what has usually been regarded as a "cœnenchyma." The corallites are tubular, crossed by well-developed tabulæ, and having their walls folded in such a manner as to give rise to a variable number (generally twelve) of septal laminæ. The cœnenchyma, so called, is composed of slender tubes, of smaller size than the true corallites, packed closely side by side, crossed, like the corallites, by regular transverse tabulæ, but destitute of septa. The soft parts occupy only the parts of the corallum above the uppermost tabulæ, and therefore only a surface-layer of the colony is actually alive. The polypes are completely retractile, with eight pinnately-fringed tentacles, and eight mesenteries. The mesenteries, however, have no correspondence with the septa, which are twelve in number as a rule. The septa are thus seen to be pseudo-septa, and they cannot be regarded as being homologous with the septa of the *Zoantharia sclerodermata*. The so-called cœnenchymal tubes are occupied by sacs lined by the endoderm, which are closed externally, but communicate freely with the body-cavities of the polypes by means of trans-

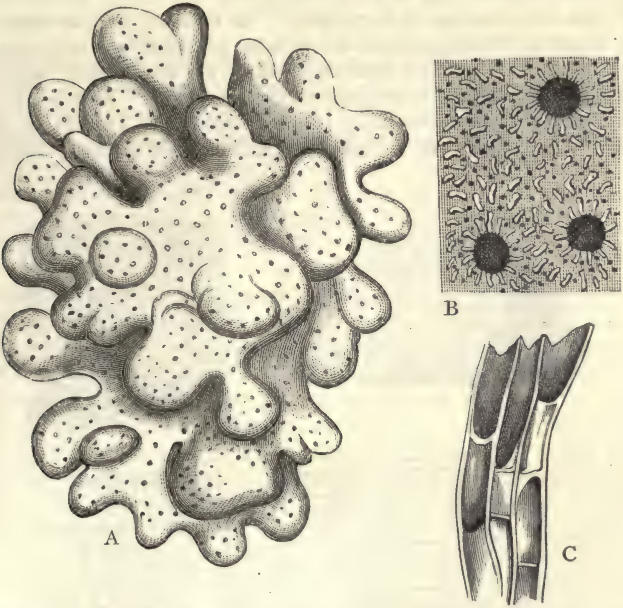

Fig. 84.—A, Colony of *Heliopora cærulea*, of the natural size. B, Portion of the surface of the same, enlarged, showing the apertures of the larger and smaller zoöids. C, Vertical section of a few of the tubes of the same, enlarged, showing the tabulæ. (After Dana.)

verse canals; and Mr Moseley suggests, with great probability, that these are really of the nature of rudimentary sexless polypes.

Now that the fact is established that the living *Heliopora* is a true *Alcyonarian*, it is necessary to remove to this order a number of well-known fossil corals, principally Palæozoic, of which *Heliolites* may be taken as the type, and which were formerly regarded as belonging to the "Tabulate" section of the *Zoantharia sclerodermata*. In *Heliolites* (fig. 85), there is a well-developed sclerodermic corallum, with comparatively large-sized, tubular, regularly tabulate corallites, usually possessing distinct but rudimentary septa, intermingled with a copious cœnenchyma formed of tabulate geometric tubuli, much smaller than the corallites, and destitute of septa. With *Heliolites* must be placed the equally extinct *Plasmopora*, *Propora*, *Polytremacis*, &c.

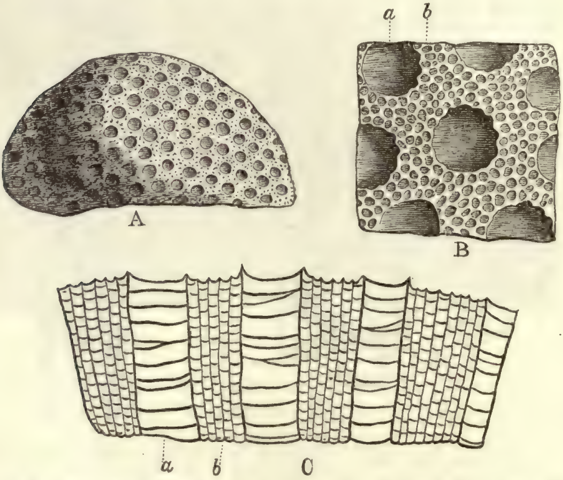

Fig. 85.—A, Small colony of *Heliolites megastoma*, of the natural size. B, Small portion of the surface of the same, magnified, showing the calices (*a*) and the mouths of the cœnenchymal tubes (*b*). C, Vertical section of the same, enlarged, showing the tabulate corallites (*a*), and the tabulate tubes of the cœnenchyma (*b*). (Original.)

CHAPTER XIV.

RUGOSA.

THE members of this order agree with the *Zoantharia sclerodermata* in possessing *a well-developed sclerodermic corallum, with a true theca, but generally possessing both tabulæ and septa combined. The septa, however, are generally (though apparently not always) some multiple of four, and there is commonly a single predominant septum (sometimes three such), or a vacant space (fossula) representing such a septum.* Some of the *Rugosa* are simple, others are compound; but the latter are destitute of a true cœnenchyma. The mode of increase in the compound forms is principally by calicular gemmation, or by lateral budding.

There are only two living genera of corals (viz., the *Guynia* of the Mediterranean and the *Haplophyllia* of Florida) which agree with the *Rugosa* in the tetrameral arrangement of the septa; and it is doubtful whether we are justified in asserting positively on this ground alone that these genera really *are* Rugose corals. We have, therefore, simply to consider very briefly the *corallum* of the Rugose corals, which alone has been preserved to us in a fossil condition. In its most essential respects, the corallum of the *Rugosa* is quite identical with that of the typical *Zoantharia sclerodermata*. In both alike the corallum may be simple or compound; in both alike the simple form of corallum (fig. 86) consists of an outer wall or "theca," enclosing a central space or "visceral chamber," which is divided into compartments by a series of radiating lamellæ or "septa;" in both alike the structures known as "dissepiments," "tabulæ," and "columella," may be developed; and in both alike the compound corallum may be regarded as a variously-formed aggregate of "corallites," similar in their fundamental structure to the simple corallum.

On the other hand, the corallum of the *Rugosa* exhibits the following more striking points of difference as compared with that of the *Zoantharia sclerodermata:* (1.) The septa appear to be primitively developed in *four* systems, instead of six or five. Sometimes the adult corallum (as in *Stauria*) exhibits the four primitive septa in a pre-eminently developed condition, but this is not commonly the case. (2.) The septa are rendered more or less irregular in their arrangement by the presence of a curious vacant space (sometimes three or four), which is known as the "fossula" (fig. 86, B, *f*), and which appears to take the place of one of the primitive four septa. (3.) When the septa are well developed, they generally present themselves in the adult as of two sizes only, a larger and a smaller (fig. 75, B). (4.) *Tabulæ* are usually present, in conjunction with the septa. (5.) The compound coralla possess no true cœnenchyma, and one of their commonest modes of increase is by means of "calicular gemmation."

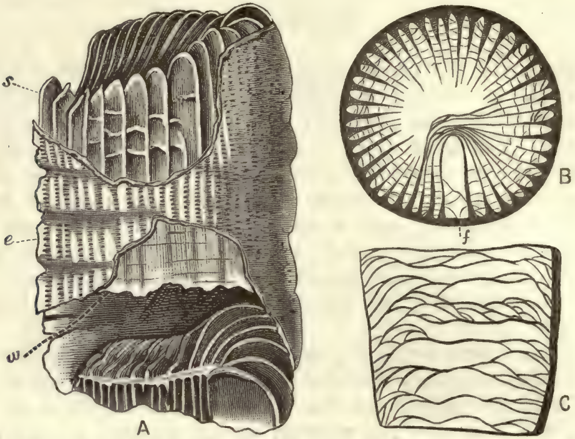

Fig. 86.—Morphology of the *Rugosa*. A, Fragment of *Zaphrentis gigantea*, showing the septa (*s*) with the sparse dissepiments crossing the interseptal loculi, the epitheca (*e*), and the thin proper wall (*w*). B, Transverse section of *Zaphrentis Guerangeri*, showing the septa and dissepiments, the central area occupied solely by the tabulæ, and the "fossula" (*f*). C, Longitudinal section of the last, showing the arrangement of the tabulæ. (A is after Edwards and Haime; B and C are after James Thomson.)

Recently it has been shown that some very abnormal Rugose corals were provided with a lid or operculum, closing the mouth of the calice. In the genus *Calceola* (fig. 88), formerly referred to the *Brachiopoda*, and very abundant in certain parts of the Devonian system, the operculum consisted of a single valve or piece. In *Goniophyllum* four valves were present, and in *Cystiphyllum prismaticum* there were four or more valves in the operculum. It is worthy of notice that some recent corals (species of *Primnoa*, *Paramuricea*, and others) exhibit also a more or less complete operculum. The calices of *Cryptohelia pudica* (one of the Hydroid group of the *Stylasteridæ*) are also protected by a calcareous lamina in front of each.

According to Professor Agassiz, the *Rugosa* ought not to be considered as belonging to the *Actinozoa*, but should be placed amongst the *Hydrozoa*. This radical change cannot, however, be accepted unless upon the production of much more evidence than has yet been brought forward in its favour. One strong argument against this view is to be found in the fact that the typical Rugose corals possess well-developed *septa*—structures which, if they do not absolutely imply the existence of *mesenteries*, are, at any rate, unknown in any living *Hydrozoön*. At present it is not possible to speak definitely as to the systematic position of the *Rugosa*, but they appear to form a natural and distinct group, intermediate in many respects between the *Zoantharia* and the *Alcyonaria*.

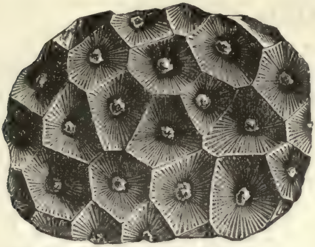

Fig. 87.—*Strombodes pentagonus*. A Silurian Rugose Coral.

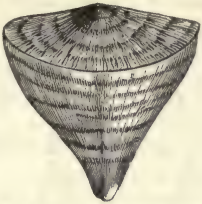

Fig. 88.—*Calceola sandalina*. An operculate Rugose Coral. Devonian.

The *Rugosa* are divided into the following families:—

1. STAURIDÆ: Septa well developed, extending from the bottom to the top of the visceral chamber, and showing a conspicuous quaternary arrangement. Dissepiments are present, and there is a central tabulate area. Genera—*Stauria*, *Polycœlia*, *Metriophyllum*, *Holocystis*, *Conosmilia*.
2. CYATHAXONIDÆ: Corallum simple, with a deep calice; septa well developed, the four primary septa not predominantly developed; no dissepiments or tabulæ. Genera—*Cyathaxonia*, *Guynia*, *Haplophyllia*.
3. CYATHOPHYLLIDÆ: Corallum simple or compound; septa well developed, but not so completely so as in the two preceding groups; the four primitive septa not pre-eminently developed; tabulæ always, and dissepiments generally, present. Genera—*Zaphrentis*, *Amplexus*, *Cyathophyllum*, *Heliophyllum*, *Omphyma*, *Lithostrotion*, *Lonsdaleia*, *Clisiophyllum*, &c.
4. CYSTIPHYLLIDÆ: Corallum simple or rarely compound; wall complete; septa rudimentary; visceral chamber with small convex vesicles formed by a combination of tabulæ and dissepiments; sometimes an operculum. Genera—*Cystiphyllum*, *Goniophyllum*, *Rhizophyllum*, *Calceola*.

CHAPTER XV.

CTENOPHORA.

Order IV. Ctenophora.—The *Ctenophora* comprise "*transparent, oceanic, gelatinous Actinozoa, swimming by means of 'ctenophores,' or parallel rows of cilia disposed in comb-like plates. No corallum*" (Greene).

The members of this order are all free-swimming organisms, and they are placed by many amongst the *Hydrozoa*, from which, however, they appear to be clearly separated by the possession of a differentiated digestive sac, as well as by their analogies with the *Actinozoa*, and their generally superior degree of organisation.

Pleurobrachia (*Cydippe*) may be taken as the type of the order, the structure of all being similar to this in essential points. *Pleurobrachia* (fig. 89) possesses a transparent, colourless, gelatinous, melon-shaped body, or "actinosoma," in which the two poles of the sphere are termed respectively the "oral" and

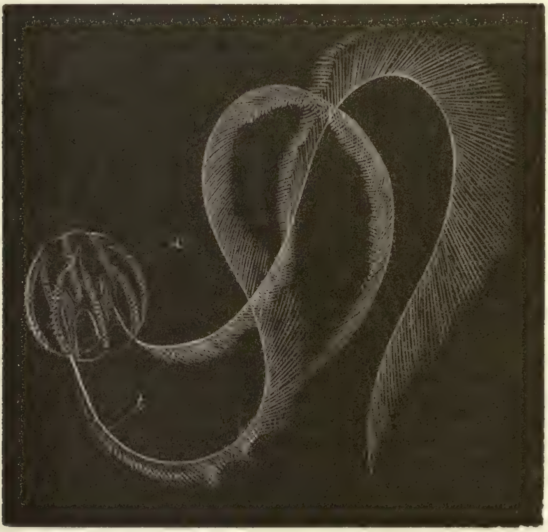

Fig. 89. — Adult of *Pleurobrachia rhododactyla*, in a natural attitude and of the natural size. (After A. Agassiz.) *c* One of the ctenophores; *t* One of the tentacles.

"apical," and the rest of the body constitutes the interpolar region. At the oral pole is the transverse mouth, bounded by lateral, slightly protuberant margins. "Eight meridional bands, or 'ctenophores' bearing the comb-like fringes, or characteristic organs of locomotion, traverse at definite intervals the interpolar region, which they divide into an equal number of lune-like lobes, termed the 'actinomeres;' but this division of the body does not extend into the immediate vicinity of the poles, before reaching which the ctenophores gradually diminish in diameter, each terminating in a point" (Greene). The normal number of the ctenophores is eight (four or twelve in some other forms), and each consists of a band of surface elevated transversely into a number of ridges, to each of which a fringe of cilia is attached, so as to form a comb-like plate. The cilia in the middle of these paddle-like transverse ridges are the longest, and they gradually diminish in length towards the sides, so that the form of each comb is somewhat crescentic. Beside the comb-like groups of vibratile cilia, *Pleurobrachia* is provided with two very long and flexible tentacular processes, which are fringed on one side with small cirrhi. These filamentous processes arise each from a sac, situated on one of the lateral actinomeres, within which they can be completely and instantaneously retracted at the will of the animal.

The mouth of *Pleurobrachia* (fig. 90, *a*) opens into a fusiform, digestive sac, or stomach (*b*), the lower part of which is provided with brown cells, supposed to discharge the functions of a liver. The stomach opens below into a shorter and wider cavity (*c*), termed the "funnel," from which two canals diverge in the direction of the vertical axis of the organism, to open at the "apical pole." These canals are known as the "apical canals" (*e*), and their apertures as the "apical pores." From the funnel two other pairs of canals are given off. Of these, one pair—known as the "paragastric canals"—turns upwards, one running parallel to the digestive sac on each side (*d*), and "terminating cæcally before quite reaching the oral extremity." The second pair of canals (*i*)—the so-called "radial canals"—branch off from the funnel laterally, each dividing into two, and then again into two, as they proceed towards the periphery of the body. Thus the two "primary" radial canals produce four "secondary" canals (*k*), and these, in turn, give rise to eight "tertiary" radial canals (*l*), which finally terminate by opening "at right angles into an equal number of longitudinal vessels, the 'ctenophoral' canals (*f*), whose course coincides with that of the eight locomotive bands. These canals end cæcally both at their oral and apical extremities" (Greene). The whole of this complex canal-system is lined by a ciliated endoderm, and a constant circulation of the included nutrient fluid is thus maintained.

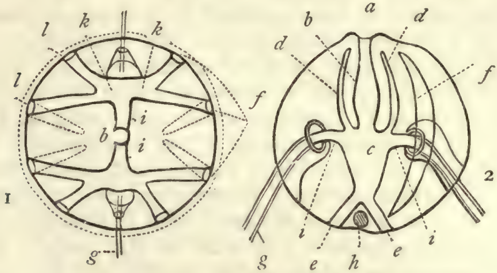

Fig. 90.—Morphology of Ctenophora. 1. Diagrammatic transverse section of *Pleurobrachia*. *b* Digestive cavity; *i i* Primary radial canals; *k k* Secondary radial canals; *l l* Tertiary radial canals; *g* Tentacle.
2. Longitudinal section of *Pleurobrachia*. *a* Mouth; *b* Digestive cavity; *c* Funnel; *d d* Paragastric canals; *e e* Apical canals; *f* Ctenophoral canals; *g* Tentacle; *h* Ctenocyst. (After Greene.)

Immediately within the apical pole is situated a small cyst or vesicle, supposed to be an organ of sense, and termed the "ctenocyst" (*h*). In structure the "ctenocyst" consists of a spherical vesicle, lined with a ciliated epithelium, and filled with a clear fluid, which contains mineral particles, probably of carbonate of lime. Just beneath the ctenocyst is a cellular mass. which has been described as giving off eight filaments running along the ctenophores, and is generally believed to be a nervous system. Eimer denies that the central ganglionic mass is nervous, but describes a plexiform nervous system. The reproductive organs of *Pleurobrachia* are in the form of folds, containing either ova or spermatozoa, and situated beneath the endodermal lining of the ctenophoral canals, one on each side.

The embryo *Pleurobrachia* is at first rudely cylindrical in form, a belt of cilia passing round the middle of its body. This soon breaks up into two lateral groups, which eventually disappear altogether. The primitive ctenophores are four in number, each ultimately breaking up into two.

As regards the homologies between *Actinia* and *Pleurobrachia*, the following may be quoted from Professor Greene:—

"If now a comparison be made between this nutrient system" (the canal-system of the *Ctenophora*) "and that of *Actinia*, the digestive sacs of the two organisms are clearly seen to correspond in form, in relative size, and mode of communication with the somatic cavity. The funnel and apical canals of *Pleurobrachia*, though more distinctly marked out, are the homologues of those parts of the general cavity, which in *Actinia* are central in position, and underlie the free end of the digestive sac. So also the paragastric and radial canals may be likened to those lateral portions of the somatic cavity of *Actinia* which are not included between the mesenteries. Lastly, the ctenophoral canals of *Pleurobrachia* and the somatic chambers of *Actinia* appear to be truly homologous, the chief difference between the two forms being, that while in the latter the body-chambers are wide and separated by very thin partitions, they are in *Pleurobrachia* reduced to the condition of tubes; the mesenteries which intervene becoming very thick and gelatinous, so as to constitute, indeed, the principal bulk of the body." The "apical" canals, again, by which the digestive sac communicates inferiorly with the external medium, may be compared with the perforation which is found in some of the *Actinidæ* (*Cerianthus* and *Peachia*) traversing the axis of the base or foot.

The remaining members of the *Ctenophora* conform in most essential respects with *Pleurobrachia*, the most important differences being found in the canal-system. For purposes of comparison this system may be divided into four portions as follows: 1. The "axial system," consisting of the mouth, stomach, funnel, and apical canals; 2. The "paraxial system," comprising the paragastric canals; 3. The "radial system," comprising the primary, secondary, and tertiary radial canals; 4. The "ctenophoral system," consisting of the tubes which run underneath the locomotive bands.

In *Beroe*, which is in other respects very similar to *Pleurobrachia*, the axial system of canals is the same as we have seen in the latter. The paraxial system, however, consists of *two* pairs of paragastric canals, which, instead of terminating cæcally, open into a circular canal which surrounds the mouth. The ctenophoral canals, likewise, open into the oral vessel, instead of terminating cæcally as in *Pleurobrachia*. Lastly, the radial system is not developed, the ctenophoral canals simply curving round towards their apical extremities, and opening into the funnel directly.

Amongst the *Beroidæ* the mouth extends entirely across the oral extremity of the body; hence they have been termed *Eurystomata*, the term *Stenostomata* being applied collectively to all the other *Ctenophora*.

The *Beroidæ* further differ from *Pleurobrachia* in being destitute of the long tentacular appendages so characteristic of the latter.

In *Cestum*, or "Venus's Girdle," "elongation takes place to an extraordinary extent at right angles to the direction of the digestive track, a flat, ribbon-shaped body, three or four feet in length, being the result."

The *Ctenophora* may be divided into the following groups :—

A. Eurystomata.—Oral aperture large, occupying the whole of the oral extremity of the body.
  1. *Beroidæ.* The paragastric canals opening into a circum-oral ring. No tentacles. Ex. *Beroe*, *Idyia.*

B. Stenostomata.—Mouth small and narrow.
  2. *Saccatæ.* No circum-oral canal; tentacles two. Ex. *Pleurobrachia*, *Eschscholtzia*, *Hormiphora.*
  3. *Lobatæ.* Body furnished with a pair of wing-like oral extensions or lobes. Ex. *Bolina*, *Mnemia*, *Eucharis*, *Lesueuria.*
  4. *Tæniatæ.* Body ribbon-like; no oral lobes; two tentacles. Ex. *Cestum.*

CHAPTER XVI.

DISTRIBUTION OF ACTINOZOA.

1. Distribution of Actinozoa in Space. 2. Coral-reefs. 3. Distribution of Actinozoa in Time.

Distribution of Actinozoa in Space. — The *Zoantharia malacodermata* appear to have an almost cosmopolitan range, Sea-anemones being found on almost every coast; some of the tropical forms attaining a very large size. Whilst essentially littoral and shallow-water forms, a few of the members of this group have been found by the Challenger expedition to extend to great depths. Thus, as shown by Mr Moseley, *Edwardsia* has been found at 800 fathoms, and *Cerianthus* at no less than 2750 fathoms; while species of *Actinia* itself go down to over 1000 fathoms. A few forms also (such as *Arachnactis*, *Nautactis*, *Plotactis*, *Oceanactis*, and *Minyas*) are pelagic in habit, and live in the open ocean. The *Antipathidæ* are principally inhabitants of warm seas; but have been found off the coast of Greenland; while they extend to great depths. The *Alcyonidæ* are principally inhabitants of shallow water; but the *Pennatulidæ* extend their range up to very great depths. The *Gorgonidæ* are likewise mostly shallow-water forms, and they attain their maximum in the seas of the tropics. The

Red Coral of commerce is a Mediterranean species, and occurs principally at depths of from 5 to 6 fathoms, though occurring at 120 fathoms or more. The Organ-pipe Corals (*Tubipora*) are confined to the warm seas of the "coral region;" and the genus *Heliopora*, the only recent representative of the family *Helioporidæ*, is confined to the Pacific and Indian Oceans. The only living corals referred to the *Rugosa* are *Guynia*, which is found in the Mediterranean, and the *Haplophyllia* of the Florida seas. The *Ctenophora* are pelagic, free-swimming forms, and appear to be cosmopolitan in their distribution. Lastly, the *Zoantharia sclerodermata* are partly inhabitants of deep water, and partly shallow-water forms; and the latter, as commonly forming "coral-reefs," are so important as to demand special consideration.

The so-called "reef-building" corals have their distribution conditioned by the mean winter temperature of the sea, a temperature of not less than 66° being necessary for their existence. The seas, therefore, which possess the necessary temperature may be said to be all comprised within a distance of about 1800 miles of the equator on each side. Within these limits, however, apparently owing to the influence of arctic currents, no coral-reefs are found on the western coasts of America and Africa. They are found chiefly on the east coast of Africa, the shores of Madagascar, the Red Sea, and Persian Gulf, throughout the Indian Ocean and the whole of Polynesia, and around the West Indian Islands and the coast of Florida. The headquarters of the reef-building corals may be said to be round the islands and continents of the Pacific Ocean. A "coral-reef" is a mass of coral, sometimes many hundred miles in length, and it may be two thousand feet or more in thickness, produced by the combined growth of different species of coralligenous *Actinozoa*. As before said, a mean winter temperature of not less than 66° is necessary for their existence, and therefore nothing worthy of the name of a "coral-reef" is to be found in seas so far removed from the equator as to possess a lower winter temperature than the above.

According to Darwin, coral-reefs may be divided into three principal forms—viz., Fringing reefs, Barrier-reefs, and Atolls, distinguished by the following characters:—

1. *Fringing-reefs* (fig. 91, 1).—These are reefs, seldom of great size, which may either surround islands, or skirt the shores of continents. These shore-reefs have no channel of any great depth intervening between them and the land, and the soundings on their seaward margin indicate that they repose upon a gently sloping surface.

2. *Barrier reefs* (fig. 91, 2).—These, like the preceding, may either encircle islands, or may skirt continents. They are distinguished from fringing-reefs by the fact that they occur usually at a much greater distance from land, that there intervenes a channel of deep water between them and the shore, and that soundings taken close to their seaward margin indicate enormous depths. If the barrier-reef surround an island, it is sometimes called an "encircling barrier-reef," and it constitutes with its island what is called a "lagoon island."

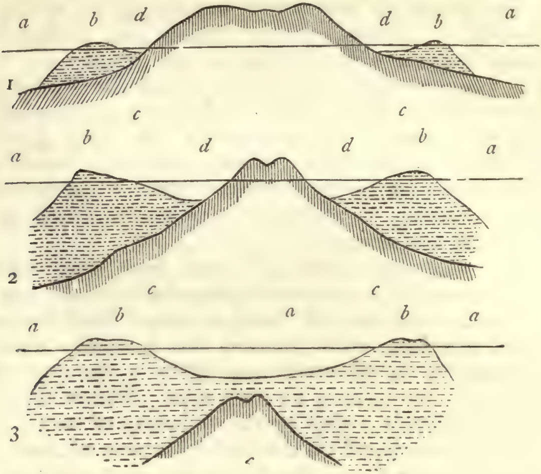

Fig. 91.—Structure of coral-reefs. 1. Fringing-reef; 2. Barrier-reef; 3. Atoll, *a* Sea-level; *b* Coral-reef; *c* Primitive land; *d* Portion of sea within the reef, forming a channel or lagoon.

As an example of this class of reefs may be taken the great barrier-reef on the N.E. coast of Australia, the structure of which is on a perfectly colossal scale. This reef runs, with a few breaches in its continuity, for a distance of more than a thousand miles, its average distance from the shore being between twenty and thirty miles, and the depth of the inner channel being from ten to sixty fathoms, whilst the sea outside is "profoundly deep" (in some places over 1800 feet).

3. *Atolls* (fig. 91, 3).—These are oval or nearly circular reefs of coral, enclosing a central expanse of water or lagoon. They seldom form complete rings, the reef being usually breached by one or more openings, which are always situated on the leeward side, or on that side which is most completely sheltered

from the prevailing winds. In their structure they are identical with "encircling barrier-reefs," and differ from these only in the fact that the lagoon which they enclose does not contain an island in its centre.

If a coral-reef be observed—say a portion of an encircling barrier-reef—the following are the general phenomena which may be noticed. The general shape of the reef is triangular, presenting a steep and abrupt wall on the seaward side, and having a long and gentle slope towards the land. The outer margin of the reef is exposed to the beating of a tremendous surf, whilst the soundings taken just outside the line of breakers always indicate great depths. The longer inner slope is washed by the calm waters of the inner lagoon or channel. The reef is only very partially composed of living corals, which are found to occupy a mere strip, or zone, along the seaward margin of the reef; whilst all above this, as well as all below, is constituted by dead coral, or "coral-rock."

As to the method in which such a reef is produced, the following facts have been established:—

A. The coral-producing polypes cannot exist at levels higher than extreme low water, exposure to the sun, even for a short period, proving rapidly fatal. It follows from this that no coral-reef can be raised above the level of the sea by the efforts of its builders. The agency whereby reefs are raised above the surface of the sea is the denuding power of the breakers which constantly fall upon their outer margins. These detach large masses of dead coral, and heap them up in particular places, until an island is gradually produced. The fragments thus accumulated are compacted together by the finer *detritus* of the reef, and are cemented together by the percolation of water holding carbonate of lime in solution. In this way the upper surface of the reef, along a line of greater or less breadth, is more or less completely raised above the level of high water. It is obvious, however, that the reef might be entirely destroyed by a continuation of this process—the sea being quite competent to undo what it had done—unless some counteracting force were brought into play. This counteracting force is found in the vital activity of the living corals, which form the seaward margin of the reef, and which, by their growth, prevent the sea from *always* destroying the masses of sediment which it may have thrown up.

B. The coral-producing polypes are essentially shallow-water animals, and cannot exist at depths exceeding some 15 to 30 fathoms. It follows from this that no coral-reef can be commenced upon a sea-bottom deeper than about 30 fathoms.

The question now arises—In what way have reefs been produced, which, as we have seen, rise out of depths of 300 fathoms or more? This question has been answered by Darwin, who showed that the production of barrier-reefs and atolls was really to be ascribed to a gradual subsidence of the foundations upon which they rest. Thus, if a fringing-reef which surrounds an island be supposed gradually to sink beneath the sea, the upward growth of the corals will neutralise the downward movement of the land, so far, at any rate, that the reef will appear to be stationary, whilst it is really growing upwards. The island, however, as subsidence goes on, will gradually diminish in size, and a channel will be formed between it and the reef. If the depression should be still continued, the island will be reduced to a mere peak in the centre of a lagoon: and the reef, from a "fringing-reef," will have become converted into an "encircling barrier-reef." As the growth of the reef is chiefly vertical, the continued depression will, of course, have produced deep water all round the reef. If the subsidence be continued still further, the central peak will disappear altogether, and the reef will become a more or less complete ring surrounding a central expanse of water; thus becoming converted into an "atoll." The production, therefore, of encircling barrier-reefs and atolls is thus seen to be due to a process of subsidence of the sea-bottom. The existence, however, of fringing-reefs is only possible when the land is either slowly rising, or is stationary; and, as a matter of fact, fringing reefs are often found to be conjoined with upraised strata of Post-tertiary age. Atolls and encircling barrier-reefs, on the other hand, are not found in the vicinity of active volcanoes—regions where geology teaches us that the land is either stationary, or is undergoing slow upheaval.

C. Different portions of a coral-reef are occupied by different kinds of corals. According to Agassiz, the basement of a coral-reef is formed by a zone of massive *Astræans*. These cannot flourish at depths of less than six fathoms of water, and consequently when the surface of the reef has reached this level, the *Astræans* cease to grow. Their place is now taken by *Meandrinas* (Brain-corals) and *Porites;* but these, too, cannot extend above a certain level. Finally, the summit of the reef is formed by an aggregation of less massive corals, such as *Madreporidæ*, *Milleporidæ*, and *Gorgonidæ*.

DISTRIBUTION OF ACTINOZOA IN TIME.—With the single exception of the Mollusca, no division of the animal kingdom contributes such important and numerous indications of its past existence as the *Actinozoa*.

In the Palæozoic rocks the majority of corals belong to the division

Rugosa, these seeming to have filled the place now taken by the sclerodermic *Zoantharia.* Until quite recently it was believed that all the *Rugosa* were Palæozoic, with the exception of the genus *Holocystis*, represented in the Cretaceous period (Lower Greensand) by the single species *H. elegans.* Recent researches, however, have brought to light the existence in our present seas of at least two genera (*Haplophyllia* and *Guynia*), which belong to the Rugose family of the *Cyathaxonidæ;* and certain Tertiary Rugose Corals (*Conosmilia*) have also been described (Martin Duncan). Of the families of the *Rugosa*, the *Cyathophyllidæ* and *Cystiphyllidæ* are exclusively Palæozoic; the *Cyathaxonidæ* are Palæozoic, but are represented by two living genera; and the *Stauridæ* are represented in the Silurian rocks (*Stauria*), Devonian (*Metriophyllum*), Permian (*Polycœlia*), and in Tertiary deposits (*Conosmilia*).

The *Zoantharia sclerodermata*, though attaining their maximum at the present day, nevertheless are well represented in past time, beginning in the Silurian period. The *Perforata* are principally represented by the *Favositidæ* during Palæozoic time, though other forms of this section are not unknown; but, like the *Aporosa*, they attain a much greater development in the Mesozoic and Kainozoic deposits.

The *Zoantharia sclerobasica* are hardly known as fossils, but the Miocene deposits of Piedmont (Middle Tertiary) have yielded a species of *Antipathes.*

The *Zoantharia malacodermata*, from the soft nature of their bodies, are obviously incapable of leaving any traces of their existence; though we are by no means therefore justified in asserting that they did not exist in past geological epochs.

With the reference of the *Helioporidæ* to the *Alcyonaria*, the range of this order has been enormously increased in past time. Formerly no example of the order was known as occurring in any Palæozoic stratum, the so-called *Protovirgularia* of the Lower Silurian being probably a Graptolite. Now we know of various abundantly distributed *Alcyonarian* corals in the Palæozoic rocks, the most important being the *Heliolites* of the Silurian and Devonian. The allied genus *Polytremacis* is Cretaceous. Of the *Gorgonidæ* two genera (*Mopsea* and *Websteria*) are found in the Eocene; and the genus *Corallium*, doubtfully quoted from the Jurassic and Cretaceous, is found in the Miocene, which has likewise yielded examples of *Isis*, *Gorgonia*, &c. The *Pennatulidæ* commence in the Eocene, with *Graphularia.* The *Tubiporidæ* (unless the Palæozoic *Syringoporidæ* be referred here) are unknown as fossils, and the *Alcyonidæ* are not known to occur till the Pliocene is reached.

The *Ctenophora*, being wholly destitute of hard structures, are not known at all as occurring in the fossil condition.

LITERATURE.

GENERAL WORKS.

1. "Manuel d'Actinologie et de Zoophytologie." De Blainville. 1834-37.
2. "Klassen und Ordnungen des Thier-Reichs," vol. ii. 'Strahlenthiere.' Bronn. 1859-60.
3. "Manual of the Cœlenterata." Greene. 1861.
4. "Essay towards a Natural History of Corallines." Ellis. 1775.
5. "Die Pflanzen-Thiere in Abbildungen." Esper. 1788-1830.
6. "Histoire des Animaux sans Vertèbres," vol. ii. Lamarck. (Ed. 2, 1836.)
7. "History of British Zoophytes." Johnston. 1847.
8. "Manual of Marine Zoology for the British Isles." Gosse. 1855.

9. "Beiträge zur Kenntniss Wirbelloser Thiere." Frey and Leuckart. 1847.
10. "Icones Histiologicæ." Abth. ii. 'Die Binde-Substance der Cœlenteraten.' Kölliker. 1866.
11. "Histoire Naturelle des Coralliaires ou Polypes proprement dits." Milne-Edwards and Haime. 1855-60.
12. "Zoophytes." 'Report of Exploring Expedition under Capt. Wilkes.' Dana. 1848.
13. "On the Alternation of Generations." Steenstrup. (Eng. Trans. by Busk.) 1845.
14. "Contributions to the Natural History of the United States." (Acalephæ, vols. iii and iv.) Louis Agassiz. 1860-62.

A. *HYDROZOA.*

I. HYDRIDA.

15. "Mémoires pour servir à l'histoire d'un genre de Polypes d'eau douce, à bras en forme de cornes." Trembley. 1744.
16. "Hydra, ein anatomisch entwickelungs-geschichtliche Untersuchung." Kleinenberg. 1872.

II. CORYNIDA, SERTULARIDA, AND CAMPANULARIDA.

17. "Monograph of the Gymnoblastic or Tubularian Hydroids." 'Ray Society.' Allman. 1871. (The first part of this work comprises an elaborate account of the Hydroida generally.)
18. "British Hydroid Zoophytes." Hincks. 1872.
19. "Recherches sur la Faune littorale de Belgique." (Polypes.) Van Beneden. 1866.
20. "Contributions to the Natural History of the United States." (Acalephæ.) Louis Agassiz. 1860-62.
21. "North American Acalephæ." 'Illust. Catalogue Mus. Comp. Zool.' No. 11. (Hydroida, pp. 64-198.) A. Agassiz. 1865.
22. "Report on the Hydroida of the Gulf-Stream." 'Memoirs of the Museum of Comparative Zoology at Harvard.' Allman. 1877.

III. OCEANIC HYDROZOA.

23. "Monograph of the Oceanic Hydrozoa." 'Ray Society.' (With a general introduction.) Huxley. 1859.
24. "Die Siphonophoren oder Schwimm-polypen von Messina." Kölliker. 1853.
25. "Siphonophoren von Nizza." 'Zoologische Untersuchungen,' ii. Leuckart. 1853.

IV. MEDUSIDÆ AND LUCERNARIDA.

[The works quoted under this section deal not only with the above-mentioned groups as here understood, but also largely with the Medusoid Gonophores of other Hydrozoa.]

26. "System der Acalephen." Eschscholtz. 1829.
27. "Die Akalephen des Rothen Meeres," &c. Ehrenberg. 1836.
28. "Acalephes." ('Suites à Buffon.') Lesson. 1843.
29. "Monograph of the British Naked-Eyed Medusæ." 'Ray Society.' Edward Forbes. 1848.
30. "Anatomy and Affinities of the Family of the Medusæ." 'Phil. Trans.' Huxley. 1849.

31. "Der Generation-Wechsel und die Fortpflanzung der Medusen." Gegenbaur. 1854.
32. "Versuch eines Systems der Medusen." 'Siebold and Kölliker's Zeitschrift,' 1857. Gegenbaur.
33. "Contributions to the Natural History of the United States." (Acalephæ, vols. ii. and iii.) Louis Agassiz. 1860-62.
34. "North American Acalephæ." 'Ill. Cat. Mus. Comp. Zool.,' ii. A Agassiz. 1865.
35. "Monograph of the Gymnoblastic or Tubularian Hydroids." 'Ray Society.' Allman. 1871.
36. "Ueber eine neue Form des Generation-wechsel's, bei den Medusen," &c. 'Monatsbericht der Kön. Akad. der Wiss. Berlin,' 1865. (Trans. Annals of Nat. Hist., 1865.) Haeckel.
37. "Beiträge zur Naturgeschichte der Hydromedusen." Haeckel. 1865.
38. "Studien über die Entwickelung der Medusen." 'Siebold and Kölliker's Zeitschrift,' 1874. Metschnikoff.
39. "Life-Histories of Animals." Packard. 1875.

V. Graptolitidæ.

40. "Graptolites de Bohême." Barrande. 1850.
41. "Ueber Graptolithen." Scharenberg. 1851.
42. "Die Graptolithen." 'Versteinerungen der Grauwacken-formation.' Geinitz. 1852.
43. "Graptolites of the Quebec Series." 'Descript. of Canadian Organic Remains.' Decade ii. Hall. 1865.
44. "British Graptolites." 'Siluria,' 4th Edition, Appendix. Carruthers. 1867.
45. "Monograph of the British Graptolitidæ." Part i., General Introduction. Nicholson. 1872.
46. "Morphology and Affinities of Graptolites." 'Annals Nat. Hist.,' 1872. Allman.

VI. Hydrocorallinæ.

47. "Contributions to the Natural History of the United States." Louis Agassiz. (The animal of *Millepora* is figured, vol. ii., pl. xv., and the genus is referred to the Hydrozoa.)
48. "Grundzüge der Zoologie." Claus. 1874.
49. "Observations critiques sur la classification des Polypiers paléozoiques." Compt. Rend. t. lxxx., 1875. Dollfus.
50. "Notes on Two Species of Millepora," &c. 'Phil. Trans.,' 1876. Moseley. (This memoir also contains a note on the structure of a Stylaster.)
51. "Structure of a Species of Millepora occurring at Tahiti." 'Annals Nat. Hist.,' 1876. Moseley.
52. "Preliminary Note on the Structure of the Stylasteridæ." 'Annals Nat. Hist.,' 1877. Moseley.
53. "On the Actinozoan Nature of Millepora alcicornis." 'Annals Nat. Hist.,' 1876. Nelson and Martin Duncan.
54. "On the Structure of the Stylasteridæ." 'Phil. Trans.,' 1878. Moseley.

B. *ACTINOZOA.*

I. ZOANTHARIA.

55. "Actinologia Britannica." Gosse. 1860.
56. "Ueber die Polypen im Allgemeinen und die Actinien insbesondere." Rapp. 1829.
57. "Mémoire sur les Edwardsies." 'Ann. Sci. Nat.,' 1842. Quatrefages.
58. "Mémoire sur le Cérianthe." 'Ann. Sci. Nat.,' 1854. Haime.
59. "Structure of Actiniæ and Corals." 'Sitzungsbericht Oberhess. Gesellsch. für Natur. und Heilkunde,' 1871. Schneider and Rötteken.
60. "Edwardsia." 'Quart. Journ. Micr. Sci.,' vol. lxii. Allman.
61. "On some New Forms of Actiniaria, dredged in the Deep Sea, with a description of certain Pelagic Surface-swimming Species." 'Trans. Linn. Soc.,' ser. 2, vol. i., 1877. Moseley.
62. "Report on Zoophytes" (with Atlas). 'U.S. Exploring Exped. under Wilkes.' Dana. 1849.
63. "Corals and Coral-Islands." Dana. 1872.
64. "Histoire Naturelle des Coralliaires ou Polypes proprement dits." Milne-Edwards and Haime. 1857-60.
65. "Beiträge zur physiologischen Kenntniss der Corallenthiere im Allgemeinen, und besonders des Rothen Meeres." 'Abh. k. Akad. Wiss. Berlin,' 1834. Ehrenberg.
66. "Developpment des Coralliaires." 'Archives de Zool. Experiment.,' 1872-73. Lacaze-Duthiers.
67. "Corals." 'Encyclopædia Brit.' 9th ed., vol. vi., 1877. Nicholson.
68. "On the Structure and Distribution of Coral-Reefs." Darwin. 1874. (2d ed.)
69. "Ueber die Natur und Bildung der Corallen-inseln und Corallenbänke im Rothen Meere." 'Abh. Kön. Akad. Wiss. Berlin,' 1834. Ehrenberg.
70. "Polypiers Fossiles des Terrains Paléozoiques." Milne-Edwards and Haime.
71. "Monograph of the British Fossil Corals." 'Palæontographical Society.' Milne-Edwards and Haime.
72. "British Fossil Corals." (Supplement to the preceding.) 'Palæontographical Society.' Martin Duncan.
73. "Introduction à l'étude des polypiers fossiles." Fromentel. 1858-61.
74. "Reports on the British Fossil Corals." 'Rep. Brit. Assoc.,' 1869-71. Martin Duncan.
75. "Deep-sea Corals." 'Illust. Cat. Mus. Comp. Zoology,' No. IV. Pourtales. 1871.
76. "On the Affinities of the Palæozoic Tabulate Corals with Existing Species." 'Amer. Journ. Sci. and Art.,' 1872. Verrill.
77. "On the Structure and Affinities of the 'Tabulate Corals' of the Palæozoic Period." 1879. Nicholson.

II. ALCYONARIA.

[Various works previously quoted are largely concerned with the *Alcyonaria*, such as Nos. 62, 63, and 64; but the following additional works may be noted :—]

78. "Anatomisch-Systematische Beschreibung der Alcyonarien." Kölliker. 1870.
79. "On the Structure and Relations of the Alcyonarian Heliopora cærulea," &c. 'Phil. Trans.,' vol. 166, 1876. Moseley.
80. "Histoire Naturelle du Corail." 'Archives Zool. Exper.,' 1872-73. Lacaze-Duthiers.

III. RUGOSA.

[The *Rugosa* are extensively, or even monographically, treated of in various works already quoted—*e.g.*, Nos. 64, 70, 71, 74; but a few additional sources of information may be indicated.]

81. "Monographie der Sclerodermata Rugosa aus der Silur-formation Estlands," &c. Dybowski. 1873.
82. "Beiträge zur Kenntniss Fossiler Korallen." Kunth. 1870.
83. "Guynia and Haplophyllia." 'Phil. Trans.,' 1872. Martin Duncan.

IV. CTENOPHORA.

[Apart from special papers, only one or two of which can be noted here, the *Ctenophora* are treated of in many of the works previously referred to, especially in Nos. 2, 3, 14, 21, 23.]

84. "Studien über Organisation und Systematik der Ctenophoren." 'Wiegm. Arch.,' 1856. Gegenbaur.
85. "Entwickelungs-geschichte der Rippenquallen." 'Mem. Acad. St Petersburg,' x., No. 4. Kowalewsky. 1866.
86. "Embryology of the Ctenophoræ." 'Mem. Amer. Acad. Arts and Sci.,' 1874. A. Agassiz.
87. "Zoologische Studien auf Capri." Eimer. 1873.

ECHINODERMATA.

CHAPTER XVII.

ECHINODERMATA.

THE *Echinodermata,* including the Sea-urchins, Star-fishes, Sea-cucumbers, &c., form a very distinctly circumscribed group of the animal kingdom, and were formerly included in the old sub-kingdom *Radiata.* To Professor Huxley is due the credit of having first pointed out that the Echinoderms possess certain remarkable affinities with the lower Worms, and especially with those "Scolecids" which constitute the order of the *Turbellaria.* So well marked are these affinities that the above-mentioned eminent zoologist at one time proposed to unite the *Echinodermata* with the *Scolecida,* to form a common division, or sub-kingdom, under the name of *Annuloida;* and there are many aspects in which this arrangement presents itself as a highly convenient one. The progress of modern Zoology has, however, shown that it is not possible to establish rigidly defined primary divisions of the animal kingdom; but that any such divisions must inevitably be more or less artificial, as including certain inosculating forms which lead by a more or less insensible gradation into neighbouring groups. Thus, in the group now in question, while there can be no doubt as to the affinities which subsist between the *Echinodermata* and the *Scolecida,* the latter, in turn, exhibit strong points of relationship with the lower *Annulosa.* While, therefore, we must not fail to recognise the points of resemblance between the Echinoderms and the Scolecids, it seems, upon the whole, best to separate the *Echinodermata* as a distinct primary division or "sub-kingdom," and to regard the *Scolecida* as a special section of the sub-kingdom *Annulosa.*

The *Echinodermata* may be defined as follows:—

Simple marine organisms, the body of the adult more or less conspicuously radiate, that of the young often distinctly bilateral.

An alimentary canal, with or without a distinct anus, but never communicating with the body-cavity. The water-vascular (ambulacral) system often subserving locomotion. Nervous system radiate, composed of an œsophageal ring and radiating branches. Sexes generally distinct, rarely united.

The members of this class are known commonly as Sea-urchins, Star-fishes, Brittle-stars, Feather-stars, Sea-lilies, Sea-cucumbers, &c.; and though the fully-grown animal often exhibits distinct traces of bilaterality, this is usually more or less completely masked by the general radiate arrangement of the parts of the body. On the other hand, the embryonic *Echinoderm* usually shows distinct bilateral symmetry. The outer layer of the general integument ("perisome") is ciliated, and the inner layer is more or less hardened by the deposition of carbonate of lime in the form of plates, granules, or spicules. In all adult *Echinoderms* there is a system of tubes, termed the "ambulacral system," which generally subserves locomotion, and usually communicates with the exterior. This water-vascular system surrounds the commencement of the alimentary canal, and in almost all cases gives off secondary vessels in a radiating manner. An alimentary canal is always present, and is completely shut off from the body-cavity. A vascular (pseudohæmal?) system is generally developed in addition to the true water-vessels. The nervous system in all the adult *Echinoderms* is a ring-like, usually gangliated cord, which surrounds the œsophagus and sends branches parallel to the radiating ambulacral canals.

The process of *development* is sometimes direct; but in the typical members of the class a characteristic form of metamorphosis occurs. The impregnated ovum gives exit to an ovoid embryo or "planula," freely locomotive by means of cilia, which are at first diffused over the body, but which soon becomes restricted to transverse bands, or to definite outgrowths of the body ("epaulettes") which are disposed with bilateral symmetry. The larva or "pseudembryo" (fig. 92) next develops an alimentary canal, with a distinct mouth and anus, dividing the embryonic body into two bilaterally symmetrical halves. A mass of actively formative protoplasm now appears on one side of the stomach, within which are developed a circular and radial tubes, the whole being the rudiment of the ambulacral system of the future *Echinoderm*. A symmetrical calcareous skeleton, not converted into that of the adult, may be developed in the larva (as in the Echinoids and Ophiuroids), or it may be wanting (as in the Asteroids and Holothuroids). The mass of protoplasm, above mentioned as developed on one side of the stomach, rapidly increases in size, envelops the stomach, which it appropriates, and is ultimately converted into the adult Echinoderm; the remainder of the larva being absorbed or cast off as useless.

The essential peculiarity of the development of the typical Echinoderms, as above summarised, is that the larva possesses provisional organs, which may be ultimately absorbed or thrown off, but which are not converted into the corresponding structures of the adult. Thus the larva of an Echinoid (fig. 92) possesses a mouth and alimentary canal, which are not converted into, and in no way correspond with, the mouth and alimentary canal of the adult. The larva, or "pseudembryo," as it is termed by Sir Wyville Thomson, leads a perfectly independent existence, and the true Echinoderm is produced from it by a process of internal budding or rearrangement.

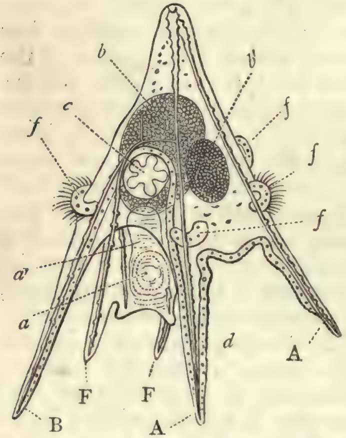

Fig. 92.—Larva of *Echinus* (after J. Müller). A A, Front arms with their internal skeleton; F F, Arms of the mouth-process; B, Posterior side-arm; *a* Mouth; *a'* Œsophagus; *b* Stomach; *b'* Intestine; *d* Ciliated bands; *f f* Ciliated epaulets; *c* Disc of the future *Echinus*.

Sir Wyville Thomson has, further, shown that there are various cases amongst the *Echinoidea*, *Asteroidea*, *Ophiuroidea*, and *Holothuroidea*, in which the young are developed directly from the egg, without the intervention of a locomotive pseudembryo. In these cases, the eggs are hatched, and the young are brought up, "within or upon the body of the parent, and are retained in a kind of commensal connection with her until they are sufficiently grown to fend for themselves." There is no sort of organic connection in these cases between the young and the parent; but the young are often brought up in a special receptacle upon the exterior of the mother, to which the appropriate name of the "marsupium" has been given. This viviparous mode of reproduction seems to obtain specially among the Echinoderms of the cold northern and southern seas.

The *Echinodermata* are divided into seven orders—viz., the *Crinoidea*, *Cystoidea*, *Blastoidea*, *Ophiuroidea*, *Asteroidea*, *Echi-*

noidea, and *Holothuroidea.* Of these, the first is to a considerable extent extinct, and the two next are entirely so; they are really the lowest orders; but their structure will be better understood if the higher orders are considered first.

CHAPTER XVIII.

ECHINOIDEA.

ORDER ECHINOIDEA.—The members of this order—commonly known as Sea-urchins—are characterised by the possession of a *subglobose*, *discoidal*, *or depressed body*, *encased in a "test" or shell*, *which is composed of numerous*, *usually immovably connected*, *calcareous plates. The intestine is convoluted*, *and there is a distinct anus. The sexes are distinct*, *and the larva is pluteiform*, *and has a calcareous skeleton.* As regards their general anatomy, the "test" of the *Echinoidea* is composed of numerous calcareous plates,* which are generally firmly united to one another by their edges, in such a manner that the body of the animal is enclosed in an immovable box. In the singular Urchins, however, which constitute the family of the *Echinothuridæ*, the plates of the test overlap one another in an imbricating manner, so that the shell becomes quite flexible; and the same is the case with some of the Palæozoic Echinoids. In all living Sea-urchins, and in the great majority of the extinct forms, the test is composed of twenty meridional rows of plates, arranged in ten alternating zones (fig. 93, A), which typically pass from one pole of the shell to the other, and each of which is composed of two similar rows of plates. Five of these double rows are composed of large plates, which are not perforated by any apertures (fig. 93, A and B, *a*); the zones formed by these imperforate plates being termed the "inter-ambulacral areas." The other five double rows of plates alternate regularly with the former, and are termed the "ambulacral areas," or "poriferous zones." Each of these zones (fig. 93, A and B, *i*) is composed of two rows of small plates, which are perforated by minute apertures for the emission of the "ambulacral tubes," or "tube-feet." In one great group of the Echinoids, the ambulacral areas pass from the centre of the base of the shell to its summit, when they are said to be "perfect" (*ambulacra perfecta*) or "simple." In another great group the ambulacral areas are not thus continuous from pole to pole, but simply form a kind of rosette upon the upper surface of the shell. In these cases—as in the common Heart-urchins—the ambulacral zones are said to be "circumscript" (*ambulacra circumscripta*) or "petaloid" (fig. 93, D). Growth of the test is carried on by additions made to the edge of each individual plate, by means of an organised membrane which passes between the sutures where the plates come into contact with one another. The plates of the test are studded with large tubercles, which are more numerous on the inter-ambulacral areas than on the ambulacral (fig. 93, B). These tubercles carry spines (fig. 93, E, and fig. 94) used defensively and in locomotion, which are articulated to their apices by means of a sort of "universal"

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* The skeleton of the Echinoids is composed of calcified areolar or connective tissue, the fibres of which enclose oval or rounded meshes (fig. 96, B), exhibiting under the microscope an exceedingly characteristic appearance.

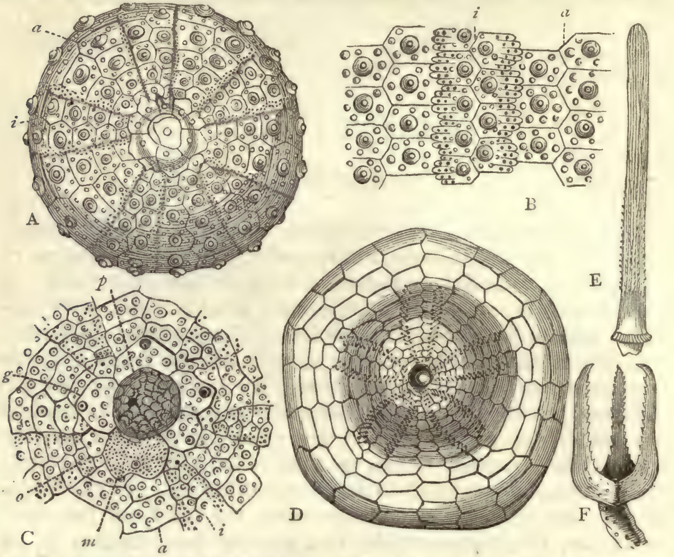

Fig. 93. — Morphology of Echinoidea. A, Young specimen of *Strongylocentrotus Dröbachiensis*, viewed from above. B, Small portion of the test of the same, magnified. C, Summit of the test of *Echinus sphæra*, magnified. D, *Clypeaster subdepressus*, viewed from above, showing the petaloid ambulacra. E, Spine of *Porocidaris purpurata*. F, Pedicellaria of *Toxopneustes lividus*. *a a* Ambulacral areas; *i i* Inter-ambulacral areas; *g* Genital plate; *o* Ocular plate; *m* Madreporiform tubercle; *p* Membrane surrounding the anus. (Figs. A, B, and D are after A. Agassiz.)

or "ball-and-socket" joint. Occasionally a small ligamentous band passes between the head of the tubercle and the centre of the concave articular surface of the spine, thus closely resembling the "round ligament" of the hip-joint of man. Besides the main rows of plates just described, forming the so-called "corona," other calcareous pieces go to make up the test of an *Echinus*. The mouth is surrounded by a coriaceous peristomial membrane, which contains a series of small calcareous pieces, known as the "oral plates;" whilst a corresponding series of "anal plates" is found in the membrane (fig. 93, C, *p*) surrounding the opposite termination of the alimentary canal. Surrounding the aperture of the anus at the summit of the test is the "apical disc," composed of the so-called genital and ocular plates (fig. 93, C). The "genital plates" are five large plates of a pentagonal form, each of which is perforated by the duct of an ovary or testis. One of the genital plates is larger than the others, and supports a spongy tubercle, perforated by many minute apertures, like the rose of a watering-pot, and termed the "madreporiform tubercle" (fig. 93, C, *m*). In some cases, this tubercle is not connected with one of the genital plates, but is placed in the centre of the apical disc. The genital plates occupy the summits of the inter-ambulacral areas. Wedged in between the genital plates, and occupying the summits of the ambulacral areas, are five smaller, heart-shaped, or pentagonal plates, known as the "ocular plates," each being perforated by a pore for the reception of an "ocellus" or "eye." (The existence of an eye-spot is denied by high authorities.)

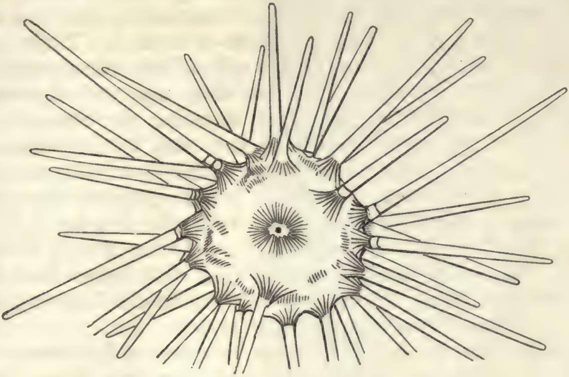

Fig. 94.—*Cidaris papillata.* (After Gosse.)

Besides the spines, which are sometimes of a very great length, the test bears curious little appendages, called "pedicellariæ" (fig. 93, F), and originally supposed to be parasitic. Each of these consists of a stem, bearing two or three, sometimes four, blades or claws, which snap together and close upon foreign objects like the beak of a bird. Their action appears to be independent of the will of the animal, and their true function is not known; but they may be regarded as peculiarly modified spines. One function performed by the pedicellariæ, in some species at any rate, is the removal of excrementitious particles of food. Such particles, on being ejected from the vent, are seized by the pedicellariæ, passed on from one to another, and ultimately entirely got rid of.

In almost all recent Urchins, the test also carries, as shown by Lovén, curious stalked appendages, with button-like heads covered with cilia. These so-called "sphæridia" are supposed to be organs of sense—probably of taste.

Locomotion in the *Echinoidea* is effected by means of a singular system of contractile and retractile tubes, which constitute the "ambulacral tubes," or "tube-feet," and are connected with the "ambulacral system" of aquiferous canals (fig. 95). From the perforated "madreporiform tubercle" on the largest of the genital plates, there proceeds a membranous canal, known as the "stone" or "sand canal" (*s*), whereby water is conveyed from the exterior to a circular tube (*r*) surrounding the œsophagus, and constituting the centre of the water-vascular or ambulacral system. The function of the madreporiform tubercle (*m*) appears to be that of permitting the ingress of water from the exterior, but of excluding any solid particles which might be injurious; and as its area is much larger than that of the stone-canal, it admits sea-water not only to the ambulacral vessels, but also to the body-cavity. It should be added, however, that the admission of water to the body-cavity through the madreporic tubercle is denied by Perrier. The "circular canal" (*r*) surrounding the gullet is situated between the nervous and blood-vascular rings, and gives off five branches—the "radiating canals"—which proceed radially along the "ambulacral areas" in the interior of the shell (*a a*). In this course they give off numerous short lateral tubes—the "tube-feet"—which pass through the "ambulacral pores" to gain the exterior of the test, and terminate in suctorial discs. Besides the radiating ambulacral canals, there are connected with the circular canal certain vesicles of unknown functions (*p p*), known as the "Polian vesicles" (*ampullæ Polianæ*). Five Polian vesicles are generally present; but some forms are wholly without these organs. The ambulacral tubes, or tube-feet, can be protruded at the will of the animal through the pores which perforate the ambulacral areas, and can be again retracted. By means of these locomotion is effected, the tube-feet being capable of protrusion to a length greater than that of the longest spines of the body. The mechanism by which the tube-feet are protruded and retracted is as follows: Each tube-foot, shortly after its origin, gives rise to a secondary lateral branch, which terminates in a vesicle. These vesicles or "ampullæ" (*v*) are provided with circular muscular fibres, by the contraction of which their contained fluid is forced into the tube-feet, which are thus protruded. Retraction of the ambulacral tubes is effected by proper muscular fibres of their own, which expel again the fluid which has been forced into them by the vesicles. The walls of the stone-canal are strengthened by calcareous deposits; and the terminations of the tube-feet contain in many forms a calcareous rosette, often with a calcareous ring below it, whilst the walls of the tube-feet are furnished with calcareous spicules.

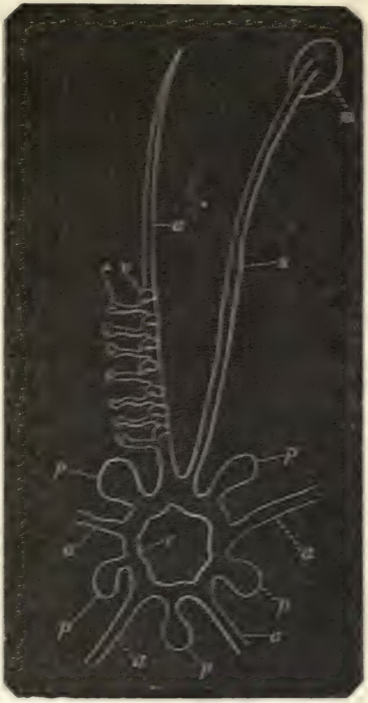

Fig. 95.—Diagram of the ambulacral system of *Echinus*. *m* Madreporiform tubercle; *s* Stone-canal; *r* Central œsophageal ring; *p p* Polian vesicles; *a a* Radiating ambulacral vessels. Only the bases of four of the radiating vessels are shown; and a few of the tube-feet (*t*), with their secondary vesicles or "ampullæ" (*v*), are shown on one side of one of the radiating canals.

The total area over which the tube-feet can be protruded depends upon the extent to which the "ambulacral" or "poriferous" zones of the test are developed. In the typical or "Regular" Sea-urchins, the ambulacral areas are "perfect," and extend from pole to pole; whereas in the so-called "Irregular" Urchins (such as the Heart-urchins and Cake-urchins), they are "interrupted," being restricted to the summit of the test, and usually being broad and petaloid (fig. 93, D).

As regards the digestive system, the mouth is typically situated in the centre of the base; but it may be excentric; and in one singular living form (*Leskia*) it is protected by valvular calcareous plates. Some forms have the mouth toothless, but others possess a complicated masticating apparatus. In *Echinus* this consists of five long, calcareous, rod-like teeth, which perforate five triangular pyramids, the whole forming a singular structure, known as "Aristotle's Lantern" (fig. 96, C).

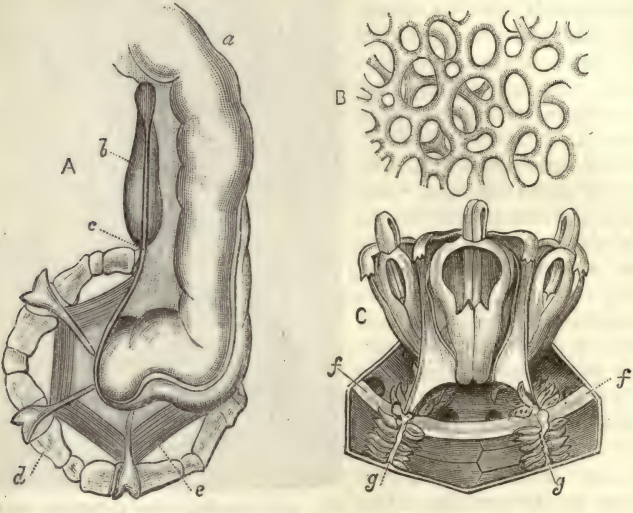

Fig. 96.—A, The masticatory apparatus of an Echinoid (*Toxopneustes lividus*), viewed from above, with part of the alimentary canal attached to it: *a* Œsophagus; *b* Heart, with the sand-canal (*c*) in a groove on one side; *d* The summit of the masticatory apparatus, with some of the muscles (*e*) of the same. B, Minute structure of one of the plates of the test of an Echinus (greatly magnified), showing the calcified areolar tissue. C, The masticatory apparatus of *Sphærechinus esculentus*, viewed from the inside and laterally, as seen in place: *f f* Peristomial margin of the corona; *g g* Two of the radiating ambulacral vessels, with their rows of ampullæ.

The mouth conducts by a pharynx and a tortuous œsophagus to a stomach, opening into a convoluted intestine, which winds round the interior of the shell, and terminates in a distinct anus. The mouth is always situated at the base of the test, and may be central, subcentral, or altogether excentric in position. The anus varies considerably in its position, being usually situated within the apical disc, and surrounded by the genital and ocular plates, when the test is said to be "regular." Sometimes, however, the anal aperture is without the apical disc, and is removed to some distance from the genital plates, when the test is said to be "irregular." In this last case, the anus, instead of being apical, is marginal or submarginal. The convolutions of the alimentary canal are attached to the interior of the test by a delicate mesentery; the surface of which, as well as that of the lining-membrane of the shell, is richly ciliated, and subserves the purposes of respiration.

The proper blood-vascular system (fig. 96 A, *b*) consists of a central fusiform, contractile vesicle, or heart. This gives off one vessel which forms a ring round the intestine near the anus, and another which passes downwards, and forms a circle round the gullet, above the "circular canal" of the ambulacral system. From the anal vessel proceed five arterial branches, which run along the ambulacral spaces, and return their blood by five branches, which run alongside of them in an opposite direction. This system of vessels is not always present, and its true nature is doubtful. High authorities regard it as rather comparable to the "pseudohæmal" system of the Annelides, than to the blood-system of the higher animals; while eminent observers maintain that the so-called heart is really of a glandular nature.

The nervous system consists of a ganglionated circular cord, which surrounds the gullet below, or superficial to, the "circular canal" of the ambulacral system, and which sends five branches along the ambulacral spaces, in company with the radiating ambulacral canals.

The process of respiration is carried on partly by arborescent gill-like organs placed round the mouth, which are of the nature of greatly developed tube-feet, and which are not universally present; partly by the tube-feet and their secondary vesicles in general; and partly by the vascular lining of the test and the mesentery. The sea-water is admitted to the body-cavity principally through the "madreporiform tubercle," only a portion of the area of this being occupied by the stone-canal; though, as previously remarked, recent observations would go to show that this view is incorrect.

The sexes are distinct in all the *Echinoidea*, and the reproductive organs are in the form of five membranous sacs, which occupy the inter-ambulacral areas, and open on the exterior by means of the apertures in the genital plates. In the "irregular" Echinoids (such as the "Heart-urchins") there are only four genital glands, and therefore only four genital plates in the apical disc.

As regards their development, most of the Echinoids pass through a metamorphosis, as spoken of previously in treating of the development of the class. In these cases the larva is so unlike the adult animal that it was originally described as a distinct animal under the name of *Pluteus*, from its resemblance to a painter's easel (fig. 92). The larva exhibits bilateral symmetry, and is furnished with provisional organs in the shape of ciliated epaulettes, a skeleton of calcareous rods, and an alimentary canal. The adult Echinoid is developed out of a portion of its substance only; and the rest of the larva is absorbed or thrown off. In some Echinoids, on the other hand, as we have seen, the process of development is direct, and there is no "Pluteus" stage, but the young animal is produced viviparously, and simply requires to grow to be converted into the adult.

The typical Sea-urchins are divided into the two great groups of the "Irregular" and "Regular" Echinoids (or the *Echinoidea exocyclica* and *Echinoidea endocyclica*). The Irregular Echinoids have the anus situated outside the apical disc, marginal or submarginal in position, and have only four genital plates. They are also mostly destitute of a masticatory apparatus; and are generally of an oblong, pentagonal, heart-shaped, or discoidal figure (as in the common "Heart-urchins" and "Cake-urchins"). The "Regular" Echinoids, on the other hand, have the anus placed at the summit of the test, surrounded by the genital disc; the test is almost always circular or spheroidal; and the mouth is armed with a complicated masticatory apparatus.

Another singular group is that of the *Echinothuridæ*, in which the test is "regular," but the plates of both the ambulacral and inter-ambulacral areas are imbricated and overlap one another, rendering the test quite flexible. The existing genera, *Asthenosoma* (or *Calveria*) and *Phormosoma*, and the Cretaceous genus *Echinothuria* belong to this group.

A fourth group of the Echinoids is that of the *Perischoëchinidæ*, which is not only extinct, but is wholly confined to the Palæozoic period. In all these ancient forms there is the peculiarity that the test consists of *more than twenty rows of plates*, there being a multiplication of either the inter-ambulacral or the ambulacral plates, though there are still only five inter-ambulacral and five ambulacral *areas*. Thus in *Archæociaaris*, *Palæchinus*, *Lepidechinus*, and *Eocidaris*, the ambulacral areas agree with those of the recent Urchins in being composed of only two rows of plates; whilst there are from three to eight or more rows of plates in each inter-ambulacral area. On the other hand, in *Melonites* and *Oligoporus*, the ambulacral areas consist, respectively, of ten and four rows of plates. In some of the *Perischoëchinidæ* the plates of the test are joined by their edges, as in the common living Urchins; but in others (*e. g.*, *Lepidechinus*) the plates overlap in an imbricating manner, as in the recent *Echinothuridæ*, and the test thus becomes flexible.

CHAPTER XIX.

ASTEROIDEA AND OPHIUROIDEA.

ORDER ASTEROIDEA (*Stellerida*).—This order comprises the ordinary Star-fishes, and is defined by the following characters:

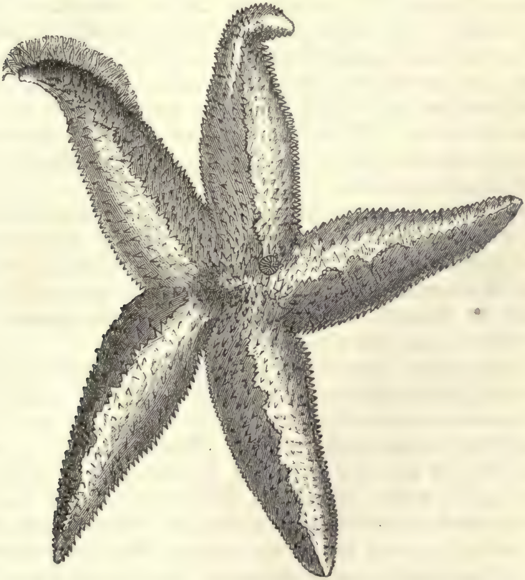

Fig. 97.—The common Star-fish (*Uraster rubens*), natural size, viewed from above.

—*The body* (fig. 97) *is star-shaped or pentagonal, and consists of a central body or "disc," surrounded by five or more lobes or* *"arms," which radiate from the body, are hollow, and contain prolongations of the viscera.* The body is not enclosed in an immovable box, as in the *Echinoidea*, but *the integument ("perisome") is coriaceous, and is strengthened by irregular calcareous plates, or studded by calcareous spines. No dental apparatus is present. The mouth is inferior, and central in position; the anus either absent or dorsal. The ambulacral tube-feet are protruded from grooves on the under surface of the rays. The larva is vermiform, and has no pseudembryonic skeleton.*

The skeleton of the *Asteroidea* is composed of a vast number of small calcareous plates, or ossicula, united together by the coriaceous perisome, so as to form a species of chain-armour. Besides these, the integument is abundantly supplied with spines, tubercles, and "pedicellariæ." Lastly, the radiating ambulacral vessels run underneath a species of internal skeleton, occupying the axis of each arm, and composed of a great number of bilateral "vertebral ossicles" or calcareous plates, which are movably articulated to one another, and are provided with special muscles by which they can be brought together or drawn apart. The upper surface of a star-fish corresponds to the combined inter-ambulacral areas of an *Echinus*, and exhibits the aperture of the anus (when present), and the "madreporiform tubercle," which is situated near the angle between two rays. The inferior or ventral surface corresponds to the ambulacral areas of an *Echinus*, and exhibits the mouth and ambulacral grooves.

The mouth is central in position, and is not provided with teeth; it leads, by a short gullet, into a large stomach, from which a pair of sacculated diverticula are prolonged into each ray. A distinct intestine and anus may, or may not, be present; but the anus is sometimes wanting (in the genera, *Astropecten*, *Ctenodiscus*, and *Luidia*).

The ambulacral system is essentially the same as in the *Echinoidea*, and is connected with the exterior by means of the "madreporiform tubercle," or "nucleus," two, three, or more of these being occasionally present. The conical or cylindrical ambulacral tube-feet are arranged in two or four rows, along grooves in the under surface of the arms (fig. 98). Each ambulacral groove is continued along the lower surface of one of the arms, tapering gradually towards the extremity of the latter. The floor of each groove is constituted by a double row of minute calcareous pieces—the "ambulacral ossicles"—which are movably articulated to one another at their inner ends. At the bottom of each groove is lodged one of the radiating canals of the water-vascular system or ambulacral system, from which are given off the rows of suctorial feet, or "tube-feet."

It follows from this that the radiating vessels of the ambulacral system are *outside* the chain of ambulacral ossicles, so that these latter are to be regarded as an *internal* skeleton, and they do not correspond with any part of the skeleton of Echinoids*—at least they do not correspond with the perforated ambulacral plates of the Sea-urchins. The ambulacral ossicles, however, of the Star-fishes are of such a form that by their apposition an aperture or pore is formed between each pair. By means of these pores (fig. 98, *a*) the tube-feet communicate with a series of little bladders or "ampullæ," placed *above* the chain of ossicles. These perforations, however, do not correspond with the perforated plates of the Echinoid test, and the tube-feet of the Star-fishes pass through no "poriferous" plates on their way to the exterior.

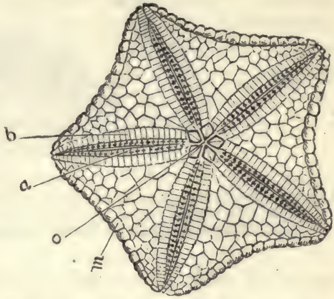

Fig. 98.—Diagram of a Star-fish (*Goniaster*), showing the under surface, with the mouth and ambulacral grooves. *a* Ambulacral ossicles, with the ambulacral pores between them; *b* Adambulacral plates, bounding the ambulacral grooves; *m* Marginal plates, (wanting in many species); *o* Oral plates, placed at the angles of the mouth.

This may be rendered more intelligible by examining a section of the arm of a Star-fish from which the soft parts have been removed (fig. 99). In such a section the ambulacral ossicles (*a a*) are seen in the centre of the lower surface, united along the middle line by their inner extremities. They are so placed as to form a kind of elongated pent-house, and immediately beneath the line where the ossicles of one side are articulated with those of the other side is placed the ambulacral vessel (*b*). Superficial to this, again, is a nerve-cord; so that the whole chain of ambulacral ossicles is placed in the midst of the soft parts of the animal, and is thus clearly an internal skeleton. At their outer extremities the ambulacral ossicles are articulated by the intervention of the "adambulacral plates" (fig. 98, *b*), with plates belonging to the external or integumentary skeleton. As before said, the shape of the ambulacral ossicles is such that a pore is formed by the apposition of each pair; and by these apertures each tube-foot communicates with a vesicle placed internal to the chain of ossicles. It will be seen, however, that the tube-feet (indicated by the dotted lines in the figure) do not pass through these apertures, or through any other pores of the skeleton, on their way to the surface. The "poriferous zones" of the Sea-urchins are part of the external skeleton, and are not represented in the Star-fishes. On the other hand, the integumentary skeleton in the Star-fishes *is absent* along the ambulacral areas, or along the areas occupied by the ambulacral grooves.

The circulatory system of the Asteroids is represented by a group of vessels communicating ventrally with an oral ring and dorsally with an anal plexus, from which branches are distributed to the genital glands. There are no distinct respiratory organs, but the surfaces of the viscera are abundantly supplied with cilia, and doubtless subserve respiration; the sea-water being freely admitted into the general body-cavity by means of numerous contractile ciliated tubes, which project from the dorsal surface of the body.

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* The structures in the *Echinus*, which are truly homologous with the ambulacral ossicles of the *Asteroidea* and *Ophiuroidea*, are the so-called "auriculæ."

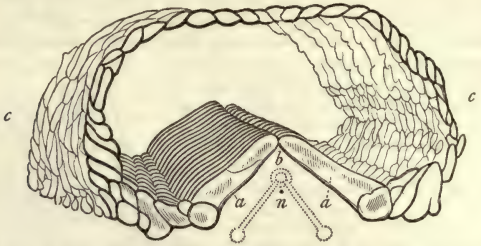

Fig. 99.—Section of the ray of *Uraster rubens*. *a a* Ambulacral ossicles; *b* Position of the ambulacral vessel; *c c* Plates of the external skeleton; *n* Nerve-cord. The dotted lines show the tube-feet proceeding from the ambulacral vessel.

The nervous system consists of a gangliated cord, surrounding the mouth and sending filaments to each of the rays. At the extremity of each ray is a pigment-spot, corresponding to one of the ocelli of an *Echinus*, and, like it, supposed to be a rudimentary organ of vision. The eyes are often surrounded by circles of movable spines, called "eyelids."

The generative organs are in the form of ramified tubes, arranged in pairs in each ray, and emitting their products into the surrounding medium by means of efferent ducts which open round the mouth. In their development, the *Asteroidea* show the same general phenomena as are characteristic of the class; but the larvæ are not provided with any continuous endoskeleton. In some *Asteroids* the larval forms have side-lappets, and have been described under the name of *Bipinnariæ;* and in these, as in the *Pluteus* of the Echinoids, a large portion of the larva is cast off as useless. In *Bipinnaria asterigera* (Sars) the digestive cavity is a simple sac which sends no prolongations into the rays, and the mouth is inter-radial, instead of being placed in the centre of the ambulacral system. The mouth of the adult is at this stage closed by the soft external skin of the larva. In other Asteroids the larvæ have three anterior vermiform processes, and are known as *Brachiolariæ.*

The general shape of the body varies a good deal in different members of the order. In the common Star-fish (*Uraster rubens*) the disc is small, and is furnished with long, finger-like rays, usually five in number (fig. 97). In the *Cribellæ* the general shape of the body is very much the same. In the *Solasters* the disc is large and well marked, and the rays are from twelve to fifteen in number, and are narrow and short (about half the length of the diameter of the body). In the *Goniasters* (fig. 98) the body is in the form of a pentagonal disc, flattened on both sides; the true "disc" and rays being only visible on the under surface of the body. In the singular genus *Brisinga*, we have in some respects a transitional form between the Asteroids and Ophiuroids, the arms being much longer and more slender than is the case in the typical Asteroids, at the same time that they are much thicker and softer than is the case amongst the latter. In none of the true Starfishes, however, are the arms ever sharply separated from the disc, as in the *Ophiuroidea*, but they are always an immediate continuation of it.

The principal groups of *Asteroidea* are the following:—

Family 1. *Asteriadæ* or *Asterocanthiidæ.*—Four rows of ambulacral feet.

Fam. 2. *Astropectinidæ.*—Two rows of ambulacral feet; back flattish, netted with tubercles, which carry radiating spines at the tip ("paxillæ").

Fam. 3. *Oreastridæ.*—Two rows of ambulacral feet; skin granular, pierced by minute pores.

Fam. 4. *Asterinidæ.*—Two rows of ambulacral feet; body discoidal or pyramidal, sharp-edged; skeleton of imbricate plates; dorsal wart single, rarely double.

Fam. 5. *Brisingidæ.*—Arms long and rounded, sharply marked off from the disc. Ambulacral grooves not reaching the mouth; two rows of ambulacral feet.

ORDER OPHIUROIDEA.—*Body stellate, consisting of a central "disc," in which the viscera are contained, and of elongated "arms," which are sharply separated from the disc, solid, not containing prolongations of the viscera, and not furnished inferiorly with ambulacral grooves. Larva generally pluteiform, with a skeleton.*

This order comprises the small but familiar group of the "Brittle-stars" and Sand-stars," often considered as belonging to the *Asteroidea*, to which they are nearly allied. The body in the *Ophiuroidea* (fig. 100) is discoidal, and is covered with granules, spines, or scales, but pedicellariæ are wanting. From the body—which contains all the viscera—proceed long slender arms, which may be simple or branched, but which do not contain any prolongations from the stomach, nor have their under surface excavated into ambulacral grooves. The arms, in fact, are not simple prolongations of the body, as in the *Asteroidea*, but are special appendages, superadded for locomotive and prehensile purposes. Each arm is enclosed by four rows of calcareous plates, one on the dorsal surface, one on the ventral surface, and two lateral. The lateral plates generally carry more or less well-developed spines. In the centre of each arm is a chain of quadrate ossicles, forming a central axis, and between this axis and the row of ventral plates is placed the ambulacral vessel. Each ossicle of the central chain is composed of two symmetrical halves, but these are immovably articulated together, and are not movable upon one another, as in the *Asteroidea*. The mouth is situated in the centre of the inferior surface of the body, is provided with a masticatory apparatus, and is surrounded by tentacles. It opens directly into a sac-like ciliated stomach, which is not continued into an intestine, the mouth serving as an anal aperture. The stomach is destitute of lateral diverticula. The reproductive organs are situated near the bases of the arms, and open by orifices on the ventral surface of the body or in the interbrachial areas.*

The ambulacral system is constructed upon the same plan as in the Echinoids and Asteroids; but its place as a locomotive apparatus is taken by the arms. The radial vessels of the ambulacral system are not provided with secondary vesicles or "ampullæ," as they are in the *Echinoidea* and *Asteroidea*, and the lateral "feet" which they give off have no terminal suckers. The madreporiform tubercle is placed on the inferior surface of the body, and is often partially concealed by one of the plates surrounding the mouth.

Respiration is carried on by the lining of the body-cavity, and by a circlet of modified tube-feet or tentacles placed round the mouth.

The development of the Ophiuroids is sometimes direct, the young being brought forth alive, and, in some cases, being carried by the mother for some period after hatching (Wyville Thomson). More commonly there is a pluteiform embryo, which resembles that of the Echinoids in having a continuous endoskeleton.

In *Euryale* the body is in the form of a subglobose disc with five obtuse angles, and the arms are prehensile. In *Asterophyton*, the Medusa-head star, the arms are divided from the base, first dichotomously, and then into many branches. In *Ophiura*, the Sand-star, the arms serve for reptation (creeping), and are undivided, often exceeding the diameter of the disc many times in length.

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* Spontaneous fission has been observed by Lütken and Kowalewsky to take place in some Ophiuroids, as also occasionally in some of the Asteroids.

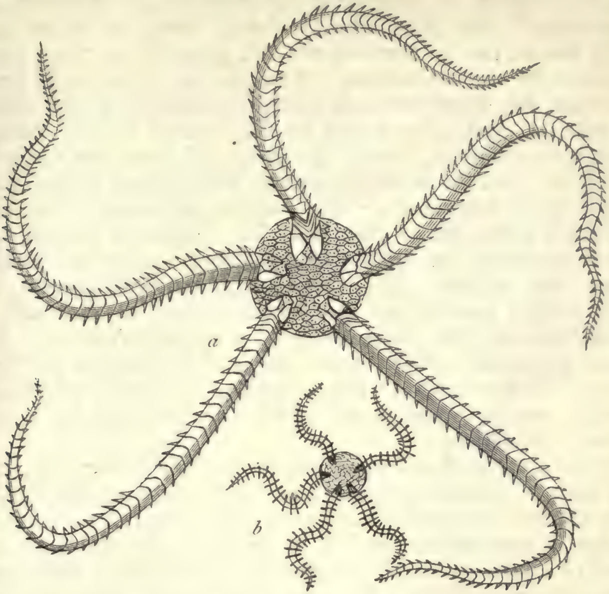

Fig. 100.—Ophiuroidea. *a Ophiura texturata*, the common Sand-star; *b Ophiocoma neglecta*, the grey Brittle-star. (After Forbes.)

The order *Ophiuroidea* may be divided into two families, as follows:—

Family 1. *Euryalidæ.*
Arms branched; genital fissures ten in number.
Fam. 2. *Ophiuridæ.*
Arms simple; genital fissures, mostly five in number.

CHAPTER XX.

CRINOIDEA, CYSTOIDEA, AND BLASTOIDEA.

ORDER CRINOIDEA.—The members of this order are *Echinodermata*, in which *the body is fixed, during the whole or a portion* *of the existence of the animal, to the sea-bottom by means of a longer or shorter, jointed, and flexible stalk.* The body is distinct, composed of articulated calcareous plates, bursiform, or cup-shaped, and provided with slender arms, which are typically five or ten in number, and are grooved on their upper surfaces for the ambulacra. (The position of the body being reversed, the *upper* surface is *ventral;* whilst the *dorsal* surface is *inferior*, and gives origin to the pedicle.) The tubular processes, however, which are given off from the radiating ambulacral canals of the *Crinoidea*, unlike those of the *Echinoidea* and *Asteroidea*, are not used in locomotion, but have probably a respiratory function. The mouth is central, and looks upwards, an anal aperture being sometimes present sometimes absent. The ovaries are situated beneath the skin in the grooves on the ventral surface of the arms or pinnules, as are also the ambulacral or respiratory tubes. The arms are furnished with numerous lateral branches or "pinnulæ." The embryo is "free and ciliated, and develops within itself a second larval form, which becomes fixed by a peduncle" (Huxley).

If we take such a living Crinoid as *Rhizocrinus* (fig. 101), we shall be able to arrive at a comprehension of the leading characters of this order. *Rhizocrinus* is one of those Crinoids which is permanently rooted to some foreign object by the base of a stalk which is composed of a number of calcareous pieces or articulations. In some cases (as in *Apiocrinus*) the base of the stem or "column" is considerably expanded. In other cases the column is simply "rooted by a whorl of terminal cirri in soft mud" (Wyville Thomson). The joints of the column are movably articulated to one another, the joint-surfaces often having a very elaborate structure, so that the entire stem possesses in the living state a greater or lesser amount of flexibility. Each joint is perforated centrally by a canal, which by the old writers was very inappropriately termed the "alimentary canal," but which in truth has nothing to do with the digestive system of the animal. At the summit of the stem is placed the body, which is termed the "calyx," and which is usually more or less cup-shaped, pyriform, bursiform, or discoidal. The calyx exhibits two surfaces, a dorsal and a ventral, of which the dorsal is composed, wholly or in part, of calcareous plates articulated by their margins, whilst the former is composed of a more or less leathery integument, strengthened by the deposition in it of numerous small plates of carbonate of lime. The ventral surface exhibits the aperture of the mouth, which may be subcentral or may be very excentric, and which in many extinct forms is wholly concealed from view. The ventral surface also exhibits the aperture of the anus, which is usually placed excentrically in one of the spaces between the arms, and which is often carried at the end of a longer or shorter tubular eminence or process, which is called the "proboscis." Owing to the animal being supported on a stalk, it is evident that the "ventral" surface is turned upwards, and the "dorsal" surface downwards. The column springs from the centre of the dorsal surface; and a stalked Crinoid may therefore be compared to a Star-fish turned upside down, with its lower or ambulacral surface superior, and its dorsal surface looking downwards. The calyx contains the digestive canal, and the central portions of the nervous and water-vascular (ambulacral) system; but it does not contain the reproductive organs, as is the case with the visceral cavity of the other Echinoderms.

From the margins of the calyx, where the dorsal and ventral surfaces join one another, arises a series of longer or shorter flexible processes, which are composed of a great number of small calcareous articulations, and which are termed the "arms" (fig. 102). The arms are usually primarily five in number, but they generally divide almost immediately into two branches, each of which may again subdivide; the branches thus produced perhaps again dividing, until a crown of delicate graceful filaments is formed. The arms carry smaller lateral

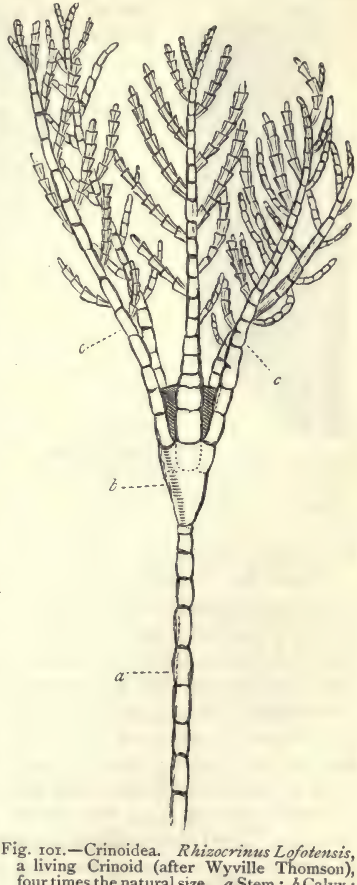

Fig. 101.—Crinoidea. *Rhizocrinus Lofotensis*, a living Crinoid (after Wyville Thomson), four times the natural size. *a* Stem; *b* Calyx; *c c* Arms.

branches or "pinnulæ" on both sides; and they contain the so-called "cœliac" and "subtentacular" canals, these being tubular extensions of the cavity of the body. The upper surface of the arms and pinnulæ is covered with a soft membrane, and below this are placed the reproductive organs. The generative organs are therefore not placed within the calyx, and it follows of necessity that there is no generative opening or "ovarian aperture" in the walls of the calyx. The ventral surfaces of the arms and pinnulæ are furnished with grooves, which in the living species are seen to be covered with vibratile cilia. The brachial grooves coalesce till they constitute five primary grooves, which are continued from the bases of the arms to the mouth. The action of the cilia gives rise to a constant current of sea-water, bearing organic matter in suspension; and this current proceeds from the brachial grooves to the mouth. In this way the animal obtains its food. As the bases of the arms are separated from the mouth by an intervening space, it follows that the brachial grooves are continued over the ventral surface of the calyx, till they reach the oral opening.

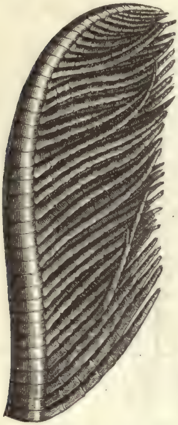

Fig. 102.—Portion of an arm of *Platycrinus*, showing the lateral pinnulæ.

There is no doubt that it is by the above arrangement that the living Crinoids obtain their food, and the mechanism seems to have been essentially the same in many extinct species. In the Palæozoic Crinoids, however, there seems to have been a modification of this arrangement. In these forms, the arms have much the structure of those of the recent Crinoids, and are deeply grooved on their ventral surfaces. The ventral surface of the calyx, however, exhibits no central aperture, but only a proboscidiform tube, which arises from one of the inter-radial spaces (*i. e.*, one of the intervals between two of the arms). This tube is almost certainly anal, but good observers regard it as discharging the functions of both mouth and anus. However this may be, the brachial grooves are certainly not continued over the ventral surface of the calyx, but stop short at the bases of the arms. Hence they are continued as covered passages or tunnels to a central point in the ventral surface of the disc. Here is placed the mouth, concealed by the calcareous plates of the perisome.

The dorsal surface of the "calyx" of the *Crinoidea* is composed of a number of calcareous plates, accurately fitted together, and having the following general arrangement (fig. 104). Resting directly upon the summit of the highest joint of the column is a series of plates, generally three or five in number, which from their position are termed the "basals" (fig. 104, *b*). Succeeding to the basals, and alternating with them, there is commonly found a second cycle of polygonal plates, which are generally termed the "parabasals" (fig. 104, *p*), and which in many forms are never developed.* Succeeding to the parabasals (or, in the absence of these, to the basals) are two or three cycles of plates, which are directly superimposed upon one another in longitudinal rows, and which form the foundations of the arms. These are known as the "radials" (fig. 104, *r*), and are termed "primary radials," "secondary radials," and "tertiary radials," according to their distance from the basals. The last radial plates, or those furthest from the column, give

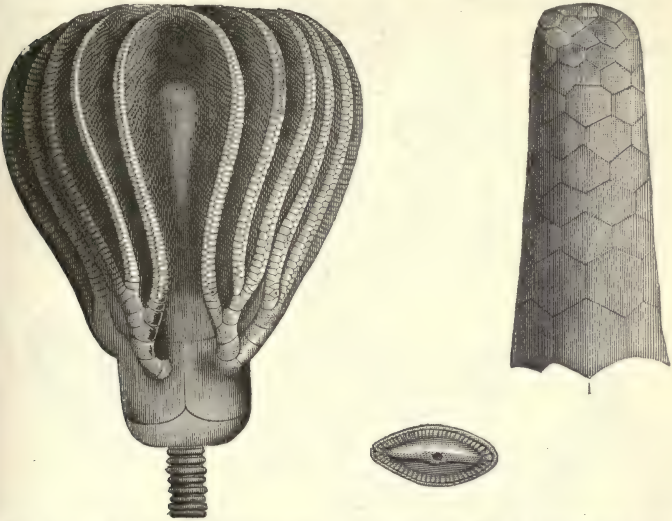

Fig. 103 —*Platycrinus tricontadactylus.* Carboniferous. The left-hand figure shows the calyx, arms, and upper part of the stem; and the figure next this shows the surface of one of the joints of the column. The right-hand figure shows the proboscis.

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* According to the high authority of Mr P. H. Carpenter, when there is only one cycle of plates between the top column-joint and the primary radials, it is the so-called "basals" (or "under-basals") which are wanting, and the cycle that is present consists of plates corresponding with the "parabasals" of such Crinoids as have two inferior cycles of calycine plates.

origin to the plates of the arms. The radial plates are arranged in a series of vertical columns, which radiate from the summit of the basals to the bases of the arms. Between the different columns of radial plates, however, there may be intercalated certain other smaller plates, which, from their position, are termed "inter-radials" (fig. 104, *i*); while one of the inter-radial spaces, corresponding with the anus, is usually much wider than the others, and is furnished with an additional series of calcareous pieces, which are termed "anal plates" (fig. 104, *a*).

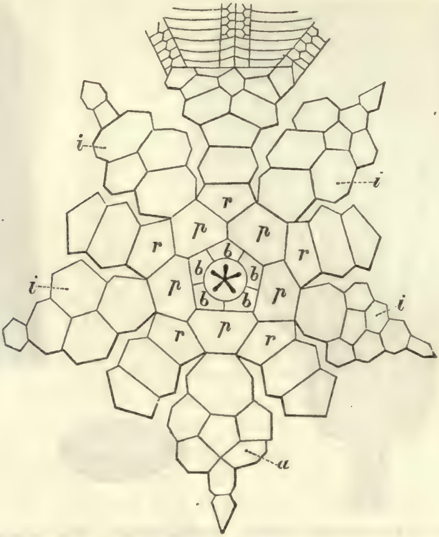

Fig. 104.—Diagram of the dissected calyx of *Rhodocrinus*, viewed from below (after Schultze). *b* Basals; *p* Parabasals; *r* First radials; *i* Inter-radials; *a* Anal plates.

Of the living stalked Crinoids, the best known is the *Pentacrinus caput-Medusæ* of the Caribbean Sea. Another West Indian form is the curious sessile *Holopus*. More recently a stalked Crinoid has been discovered in the Atlantic and North Sea, and has been described under the name of *Rhizocrinus Lofotensis* (fig. 101). The chief interest of this form is the fact that it belongs to a group of the *Crinoidea* hitherto believed to be exclusively confined to the Mesozoic rocks—viz., the *Apiocrinidæ* or "Pear-encrinites." In fact, *Rhizocrinus* is very closely allied to the Cretaceous genus *Bourgueticrinus*, and it may even be doubted if it is generically separable from it. The late remarkable researches into the life of the deeper parts of the ocean have brought to life several new Crinoids, which will doubtless, when fully investigated, still further fill up the interval between the living and extinct *Crinoidea*. Amongst these may be mentioned *Pentacrinus Wyville-Thomsoni*, *Bathycrinus gracilis*, and *Hyocrinus Bethellianus*.

In the second type of the *Crinoidea*—represented in our seas by the forms which are commonly known as "Feather-stars," and which are grouped together under the general name of *Comatula*—the animal is not permanently fixed, but is only attached by a stalk when young. Taking the British *Comatula* (*Antedon*) *rosacea* as the type of this group, the larva, after various preliminary embryonic changes, appears as a small stalked Crinoid (fig. 105, *b*), in which state it was described as a distinct species under the name of *Pentacrinus Europæus*.

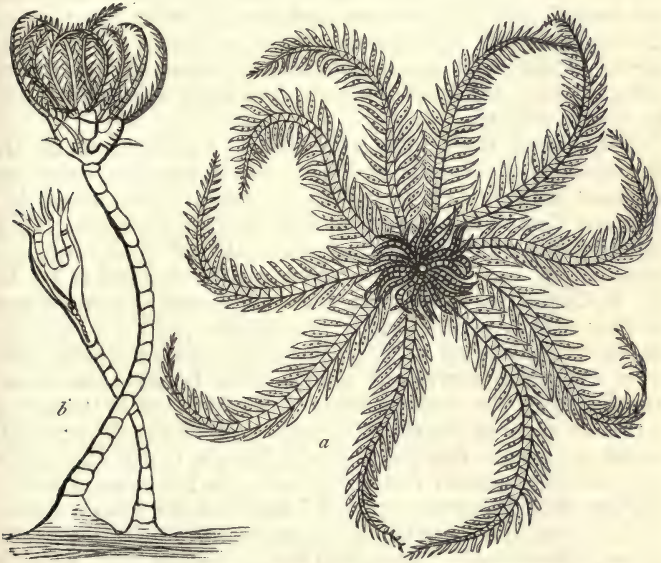

Fig. 105.—Crinoidea. *Comatula* (*Antedon*) *rosacea*, the Feather-star. *a* Free adult; *b* Fixed young. (After Forbes.)

In its adult condition, however, the *Comatula* (fig. 105, *a*) is free, and consists of a pentagonal disc, which gives origin to ten slender arms, which are fringed with many marginal pinnulæ. The mouth and anus are on the ventral surface of the disc, which in this case is again the inferior surface, since the animal has the power of creeping about by means of its pinnated arms. Though capable of creeping, the animal more usually has recourse to swimming, the five left arms working as paddles simultaneously, and alternating in their action with the five right arms. The arms of *Comatula rosacea* exhibit on their ventral surface a deep "brachial groove," the elevated margins of which are cut out into minute crescentic respiratory leaves, at the base of each of which is a group of three tentacles, connected with a cavity in the interior of the respiratory leaf, and communicating by a common trunk with the radiating ambulacral vessel. The floor of the brachial grooves is ciliated, and underneath each runs a radiating ambulacral vessel, together with a blood-vascular trunk, and a peculiar fibrillar "sub-epithelial band," which is supposed to be of a nervous nature. In some Comatulids (certain *Actinometræ*) there is the curious feature that some of the arms in some individuals may want the ventral grooves, tentacles, and nerves, while in other individuals all the arms possess these structures. The dorsal surface of the calyx, again, carries a tuft of jointed filaments or cirri, by which the animal is enabled to moor itself temporarily to foreign objects.

The animal feeds upon very minute organisms which are conveyed to the mouth by the action of the cilia lining the brachial grooves. The mouth in *C. rosacea* is sub-central, but in some Comatulids (*Actinometra*) it is quite excentric; while the anus is usually supported on a tubular projection and situated on one side. According to the researches of Dr W. B. Carpenter, the nervous system of *Comatula* consists of a fibrillar sheath surrounding a central quinquelocular vascular organ, and giving off a series of radial branches which differ from the radial nerve-cords of the other Echinoderms in not running along the ventral surface of the arms, but in occupying a median canal in the centre of each arm. While the principal nerve-cords have this position, and have a motor function, it has also been shown that there exists, as before remarked, a fibrillar band below the epithelial lining of the ventral furrow of each arm, and these bands are supposed to be of the nature of sensitive nerves. They spring from a circular band, which is placed round the gullet, above the ambulacral and blood-vascular rings. It has also been shown by modern researches, that there exists in *Comatula* a complicated blood-vascular system.

As regards the vascular system of the Crinoids generally, there is found in *Comatula*, occupying the dorso-ventral axis of the body, a largish lobated structure homologous with the heart of the Asteroids, and, like it, consisting of numerous closely-packed vessels. Dorsally, these resolve themselves into a central group (of one or more) and five peripheral vessels, the latter of which expand in the calyx into the five chambers of the "chambered organ," the chambers and axis alike giving branches to the dorsal cirri. In the pedunculate Crinoids in which there are no cirri, the chambers narrow again, and the group of vessels is continued down the central canal of the column. In *Pentacrinus*, which has cirri at regular intervals, the five peripheral vessels expand in each cirrus-bearing joint into five dilatations, which thus give rise to a miniature "chambered organ," each chamber of which gives off a single vessel to a cirrus. In the body, the vascular axis is connected with (1) a large network of vessels round the alimentary canal, (2) an extensive plexus beneath the ventral surface of the disc, in which vessels arise that run out into the arms and enclose the genital glands, and (3) a plexus of convoluted tubes depending from the oral blood-vascular ring in which the radial vessels of the arms originate (P. H. Carpenter).

The reproductive organs of *Comatula* are situated beneath the soft skin of the arms, and their ducts open into the pinnulæ, by the rupture of the ventral integument of which the generative elements are set free into the surrounding water.

As regards the development of *Comatula*, the larva is at first cylindrical, with four transverse bands of cilia, a hinder tuft of cilia, and an alimentary canal furnished with a lateral aperture, its general aspect closely resembling that of the embryos of certain Annelides. The skeleton of the calyx is developed anteriorly, that of the column posteriorly, the former being the first to appear. In its early condition (fig. 106) the calycine skeleton consists of a row of five "basal" plates, which rest below upon the so-called "centro-dorsal plate," and are succeeded above by a cycle of five "oral" plates, in the centre of which the permanent mouth is finally developed. Five "radial" plates are next developed as a cycle between the oral and basal plates; and to the radials are rapidly added the plates of the arms proper (the "brachial" plates). Inferiorly, the centro-dorsal plate rests upon a short, jointed column (fig. 106, *c*), the lowest plate of which is expanded to form a disc of attachment; and the larva now passes into what is known as its "Pentacrinus stage." In the further progress of growth the arms increase in length, and the oral plates diminish in size and ultimately disappear. At the same time the centro-dorsal plate increases in size, so as to enclose the radial plates, which in turn become fused with one another, and remain only as the so-called "rosette" on the upper surface of the centro-dorsal. The latter also develops jointed cirri from its outer surface, and finally becomes detached from the next joint of the column below, when the animal enters upon its free stage of life.

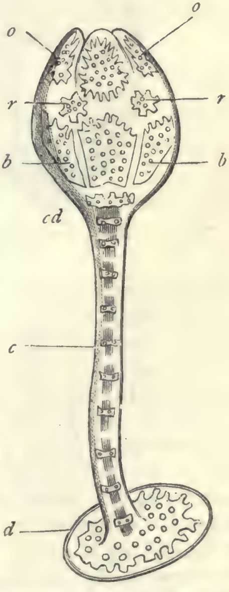

Fig. 106.—Larva of *Comatula* (*Antedon*) *rosacea*, enlarged (after Sir Wyville Thomson). *o o* Oral plates; *r r* Radial plates; *b b* Basal plates; *c d* Centro-dorsal plate; *c* Column; *d* Disc of attachment.

Numerous living forms of *Comatula* are known, and have been described under various subordinate types (*Antedon*, *Actinometra*, *Comaster*, and *Phanogenia*); and the group seems to be cosmopolitan in its distribution.

ORDER CYSTOIDEA.—*Body generally spheroidal, pedunculate or sessile, enclosed by calcareous articulated plates, some of which are usually porous and are connected with respiration, and perhaps with reproduction also. Arms rudimentary, mostly reduced to the pinnulæ only. Reproductive organs contained within the interior of the calyx.*

The members of this order are all extinct, and are entirely confined to the Palæozoic period. The body (fig. 107) was, typically, more or less spherical, and was protected by an external skeleton, composed of numerous polygonal calcareous plates accurately fitted together, and enclosing all the viscera of the animal. The body was in most cases permanently attached to the sea-bottom by means of a jointed calcareous "column," or pedicle, but this was much shorter than in the majority of *Crinoids*, and was rarely altogether absent. Upon the upper surface of the body were two, sometimes three, apertures, the functions of which have been a matter of considerable controversy. One of these is lateral in position, is defended by a series of small valvular plates, and is believed by some to be the mouth, whilst by others it is asserted to have been an ovarian aperture. The most probable view, however, is that this valvular opening is really the anus. The second opening is central in position, and it is believed by Mr Billings to be the "ambulacral orifice," as it is always in the centre of the arms when these are present. The third aperture is only occasionally present, and its true functions are doubtful.

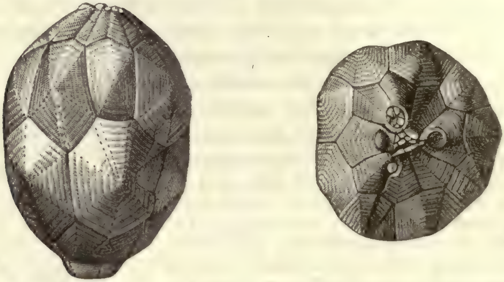

Fig. 107.—*Hemicosmites pyriformis*, one of the Cystideans. The right-hand figure shows the upper surface of the calyx.

In some *Cystoidea* there were no arms, properly speaking, but only small pinnulæ. In a second section two arms were present, but these were bent backwards, and were immovably soldered down to the body. In one single species (*Comarocystites punctatus*, Billings), the development has gone further, the arms being free, and provided with lateral pinnulæ, as in the true *Crinoids.*

Many Cystideans are likewise provided with a system of pores or fissures, penetrating the plates of the body, and usually arranged in definite groups. These groups are termed "pectinated rhombs," but their exact function is doubtful. By Mr Billings, however, they are believed, and apparently with good reason, to have admitted water to the body-cavity, and to have thereby subserved a respiratory function; though the recent researches of Ludwig on the genital glands of the Ophiuroids would render it not improbable that they were also connected with the function of reproduction.

ORDER BLASTOIDEA.—*Body enclosed in an armour of closely fitting calcareous plates, attached to some foreign body by a slender stem. From the summit of the calyx radiate five transversely striated and longitudinally grooved areas, which carry a row of jointed pinnulæ on each side.*

The members of this order, like those of the preceding, are all extinct, and are entirely confined to the Palæozoic period. The body (fig. 108, *a*) was fixed to the bottom of the sea by means of a short, jointed pedicle; it was globular or oval in shape, and composed of solid polygonal calcareous plates, firmly united together, and arranged in five inter-ambulacral and as many ambulacral areas. (These ambulacral areas are

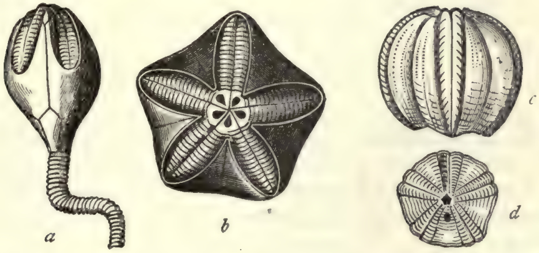

Fig. 108.—Morphology of Blastoidea. *a Pentremites pyriformis*, viewed sideways, showing a portion of the column; *b* Summit of the calyx of *Pentremites cervinus*, showing the pseud-ambulacral areas and the apical apertures; *c* Side view of *Granatocrinus melonoides*; *d* Summit of *Granatocrinus neglectus*. (Figs. *a* and *b* are of the natural size; *c* and *d* are slightly enlarged.) After Hall, and Meek and Worthen.

termed by M'Coy "pseud-ambulacra," upon the belief that they were not pierced for tube-feet, but that they carried a double row of little jointed tentacles or arms.) The pseud-ambulacra are petaloid in shape, having a deep furrow down the centre, and striated transversely. They converge to the summit of the calyx (fig. 108, *b*), and each appears to have carried a row of small jointed "pinnulæ" upon each side. The five pseud-ambulacra, radiating from the summit of the calyx, give the upper surface of the body somewhat the appearance of a flower-bud; hence the name applied to the order (Gr. *blastos*, a bud; *eidos*, form). Upon the whole, it would seem most probable that the pseud-ambulacra of the *Pentremites* represent the *arms* of the Crinoids, anchylosed with the calyx, and that the longitudinal furrows of the pseud-ambulacra represent the "brachial grooves" of the Crinoids; but they are peculiar in the fact they are perforated by the apertures of a number of respiratory tubes.

At the summit of the calyx are six apertures, of which one is the mouth, four are ovarian, and the sixth is probably partly ovarian and partly anal.

The *Blastoidea* are known more familiarly under the name of *Pentremites*, and they occur most commonly in the Carboniferous rocks.

CHAPTER XXI.

HOLOTHUROIDEA.

ORDER HOLOTHUROIDEA.—*Vermiform or slug-like Echinoderms, with a leathery skin, in which calcareous granules and spicules are generally developed. Mouth surrounded by a circlet of tentacles. Sexes mostly distinct. Larva vermiform, without a skeleton.*

The members of this order are commonly known by the name of "sea-cucumbers," "trepangs," or "béches-de-mer," and are the most highly organised of all the *Echinodermata*. The body is elongated and vermiform, or rarely slug-shaped, and is not provided with a distinct test, but is enclosed in a coriaceous skin, generally, but not always, containing calcareous deposits in the form of scattered granules or spicules, or even imbricated scales. The ambulacral tube-feet, when present, are typically disposed in five rows, which divide the body into an equal number of longitudinal segments or lobes. The mouth is surrounded by a circlet of feathery tentacles, containing prolongations from the central ring of the water-vascular system; and an anus is situated at the opposite extremity of the body. There is a long, convoluted intestine. A special respiratory, or water-vascular, system is often developed, in the form of a system of arborescent tubes, which admit water from the exterior. The larva is vermiform, and has no skeleton. At a certain period of their existence, the young Holothurians are barrel-shaped, with transverse rings of cilia (fig. 109, *c*).

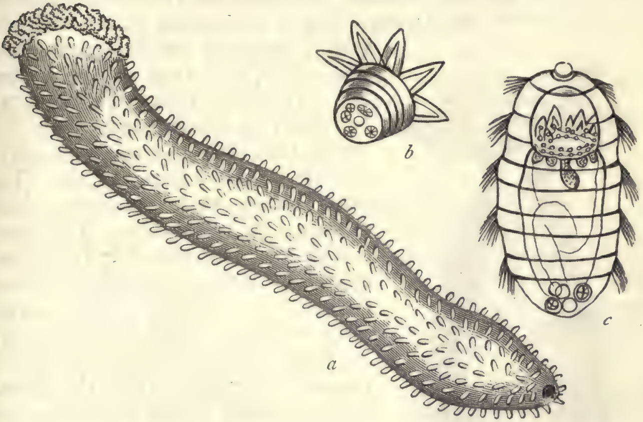

Fig. 109.—Holothuroidea. *a Holothuria tubulosa,* one of the Sea-cucumbers *b* and *c* Young stages of the same.

They rotate rapidly on their long axis, and have at this stage been described as a distinct genus under the name of *Auricularia.*

In the typical Holothurians, locomotion is chiefly effected by means of rows of ambulacral tube-feet, or by alternate extension and contraction of the worm-like body; but in the *Synaptidæ,* in which there are no ambulacra, and only the central circular canal of the ambulacral system is present, the animal moves by means of variously shaped spicula, which are scattered in the integument. When developed, the ambulacral system consists of a "circular canal," surrounding the mouth, bearing one or more "Polian vesicles," and giving off branches to the tentacula; and of five "radiating canals" which run down the interspaces between the great longitudinal muscles. These radiating canals give off the tube-feet and their secondary vesicles, just as in the *Echinus.* In the typical forms there are five rows of tube-feet, but these organs may be scattered over the whole body, or may be restricted to the ventral surface. There is also a "sand-canal" which arises from the circular canal, and is terminated by a madreporiform tubercle; but this, instead of opening on the exterior, hangs down freely in the perivisceral cavity. The fluid, therefore, with which the ambulacral system is filled, is derived from the perivisceral cavity, and not from the exterior, as is usually the case.

The mouth is toothless, is situated anteriorly, and is surrounded by a beautiful fringe of branched, retractile tentacles (fig. 110), which arise from a ring of calcareous plates, and into which are sent prolongations from the circumoral ring of the ambulacral system. These tentacles, ten to twenty in number, are really modified tube-feet, and probably serve in part as respiratory organs. The mouth opens into a pharynx, which conducts to a stomach. The intestine is long and convoluted, and usually opens into a terminal dilatation, termed the "cloaca," which serves both as an anus and as an aperture for the admission of sea-water to the respiratory tubes. From the cloaca arise, in many forms, two branched and arborescent tubes, the terminations of which are cæcal. These run up towards the anterior extremity of the body, and together constitute the so called "respiratory tree." They are highly contractile, and they perform the function of respiratory organs, sea-water being admitted to them from the cloaca. The vascular system consists of two main vessels—one dorsal, and the other ventral—connected with a circum-œsophageal ring. Development is in a few instances direct; but in most cases there is a metamorphosis, the larva being vermiform, and devoid of a skeleton. The nervous system consists of a cord, surrounding the gullet, and giving off five branches which run alongside of the radiating ambulacral canals. The sexes are generally,

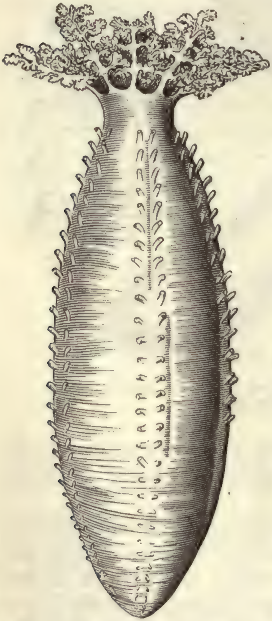

Fig. 110.—*Pentacta frondosa*, showing the crown of feathery tentacles round the mouth and the rows of tube-feet.

but not universally, distinct. The generative organs are in the form of long, ramified, cæcal tubes, which open externally by a common aperture, situated near the mouth. There is thus no trace of that radial symmetry which is observed in the arrangement of the reproductive organs in the other orders of the *Echinodermata.*

The skin in the Holothurians is highly contractile, and the body is provided with powerful longitudinal and circular muscles, in compensation for the absence of any rigid integumentary skeleton. Many of the Sea-cucumbers, in fact, are endowed with such high contractility that they can eject their internal organs entirely, if injured or alarmed.

In the family of the *Synaptidæ* there is no respiratory tree, and the ambulacral tube-feet are wanting; whilst the skin is furnished with calcareous spicules of various shapes. The *Synaptæ* themselves burrow in the mud or sand, and have the skin furnished with innumerable anchor-shaped spicules (fig. 111) attached to special "anchor-plates" in the integument. They often form a kind of protective case or tube of sand-grains; and they obtain their food by swallowing the mud, from which they extract any disseminated nutrient particles. In *Chirodota* the skin is provided with microscopic calcareous wheels, in the place of anchors. In the *Oncinolabidæ*, the skin has barbed spicules, and there is no respiratory tree; but these forms differ from the *Synaptidæ* proper in possessing tube-feet.

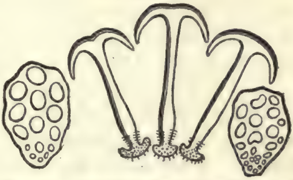

Fig. 111.—Anchor-shaped spicules of *Synapta*, and the plates to which these are attached. Magnified greatly.

The order *Holothuroidea* is divided into the two following sub-orders:—

Sub-order 1. *Apneumona.*

No respiratory tree. The ambulacral tube-feet wanting (*Synaptidæ*), or present (*Oncinolabidæ*).

Sub-order 2. *Pneumonophora.*

A respiratory tree. (Ex. *Holothuria*, *Thyone*, *Molpadia*, *Psolus*, *Cucumaria*, &c.)

CHAPTER XXII.

DISTRIBUTION OF ECHINODERMATA IN SPACE AND TIME.

Distribution of Echinodermata in Space.—The *Crinoidea* are represented by comparatively few forms in recent seas, and these have mostly a very local distribution. More than one hundred and fifty species of *Comatula* (in the wide sense) are known, ranging from 82° N. lat. to Kerguelen's Land, but most abundant in the tropics. *Holopus* is a West Indian form, and the species of *Pentacrinus* are principally West Indian also. *Rhizocrinus Lofotensis* occurs in the North Atlantic, and another species of this genus is found in the Gulf of Mexico. Lastly, the species of *Bathycrinus* and *Hyocrinus* are found at great depths in the Atlantic and Pacific.

The *Asteroidea*, *Ophiuroidea*, and *Echinoidea* are represented in almost all seas, whether in tropical or temperate zones, extending their range even into high northern and southern latitudes. They have also a wide bathymetrical range, extending from between tide-marks to almost the greatest depths which have yet been explored by the dredge. Some of the Sea-urchins (such as *Toxopneustes lividus*) have the peculiar habit of hollowing out cavities for themselves in the solid rock, in which they spend their existence. The *Holothuroidea* enjoy a nearly world-wide distribution; but they have their metropolis in the Pacific Ocean, occurring abundantly on the coral-reefs of the Polynesian Archipelago. One species (*Holothuria argus*) is collected in large numbers, and is exported to China, where it is regarded as a great delicacy.

Distribution of Echinodermata in Time.—Numerous remains of *Echinodermata* occur in most sedimentary rocks, beginning with the Upper Cambrian rocks, and extending up to the recent period. The two orders *Cystoidea* and *Blastoidea*, which are the most lowly organised of the entire class, are exclusively Palæozoic; and the *Crinoidea* are mostly referable to the same epoch. The more highly organised *Asteroidea* and *Ophiuroidea* commenced to be represented in the Silurian period; but the *Echinoidea*, with few exceptions, have no representatives earlier than the Carboniferous rocks. The following exhibits the geological distribution of the different orders of the *Echinodermata* in somewhat greater detail:—

1. Crinoidea.—The pedunculate *Crinoidea* attained their

maximum in the Palæozoic period, from which time they have gradually diminished down to the present day. On the other hand, the free Crinoids are comparatively modern, and seem to have reached their maximum at the present day. As has already been described, the Palæozoic *Crinoidea* differ in some important particulars from those which succeeded them. The order is well represented in the Silurian, Devonian, and Carboniferous rocks, but especially in the latter; many Carboniferous limestones (crinoidal limestones and entrochal marbles) being almost entirely made up of the columns and separate joints of Crinoids. In the Secondary rocks Crinoids are still abundant. In the Trias the beautiful "Stone-lily" (*Encrinus liliiformis*) is peculiar to its middle division (Muschelkalk). In the Jurassic period occur many species of *Apiocrinus* (Pear-encrinite), *Pentacrinus*, and *Extracrinus*. The Chalk also abounds in Crinoids, amongst which is a remarkable unattached form (the Tortoise-encrinite or *Marsupites*).

Of the non-pediculate *Crinoidea*, which are a decided advance upon the stalked forms, there are comparatively few traces; but remains of forms (such as *Saccosoma* and *Solanocrinus*) allied to the recent *Comatulæ* have been found in the Jurassic and Cretaceous deposits.

2. BLASTOIDEA.—The *Blastoidea*, or Pentremites, are entirely Palæozoic, and attain their maximum in the Carboniferous rocks, some beds of which in America are known as the Pentremite limestone, from the abundance of these organisms. They are, however, also found in the Silurian and Devonian rocks.

3. CYSTOIDEA.—These, like the preceding, are entirely Palæozoic; but they are, as far as is yet known, almost exclusively confined to the Upper Cambrian and Silurian rocks, being especially characteristic of the horizon of the Bala limestone. The last known forms of Cystideans occur in the Devonian rocks. The oldest known Echinoderms are two extremely simple Cystideans (*Trochocystites* and *Eocystites*) which have been discovered in the primordial zone of North America.

4. ASTEROIDEA.—These have a very long range in time, extending from the Lower Silurian period up to the present day. In the Silurian rocks the genera *Palæaster*, *Stenaster*, *Palæodiscus*, and *Petraster* are among the more important, the greater number of forms being Upper Silurian. The next period in which Star-fishes more especially abound is the Oolitic (Mesozoic); the more important genera being *Uraster*, *Luidia*, *Astropecten*, *Plumaster*, and *Goniaster*, some of which have survived to the present day. Many Star-fishes occur, also,

in the Cretaceous rocks, the genera *Oreaster*, *Goniodiscus*, and *Astrogonium* being among the more noticeable. In the Tertiary rocks few Star-fishes are known to occur, but *Goniaster* and *Astropecten* are represented in the London Clay (Eocene).

5. OPHIUROIDEA.—The "brittle-stars" are represented in the Silurian rocks by some anomalous genera, of which the best known is *Protaster*. In the Triassic, Oolitic, Cretaceous, and Tertiary rocks various genera of *Ophiuroidea* are known; some being extinct, whilst others still survive at the present day.

6. ECHINOIDEA.—This order is represented in the Palæozoic rocks by a single aberrant family; but it is numerously represented in the Mesozoic and Kainozoic periods.

Of the Palæozoic Urchins or *Perischoëchinidæ*, the two most abundant genera are *Archæocidaris* and *Palæchinus*, both of which are principally Carboniferous, though the latter occurs in the Upper Silurian. *Melonites* and *Oligoporus* are exclusively Carboniferous; and *Lepidechinus* and *Eocidaris* are principally so, though both commence their existence in the Devonian.

The Secondary and Tertiary *Echinoidea* resemble those now living in being composed of not more than twenty rows of calcareous plates. The Oolitic and Cretaceous rocks are especially rich in forms belonging to this order, many genera being peculiar; but the number of forms is too great to permit of any selection.

It may be mentioned, however, that the singular genus *Echinothuria*, with its flexible test, the predecessor of the living *Asthenosoma* and *Phormosoma*, is found in the Chalk.

7. HOLOTHUROIDEA.—This order, comprising, as it does, soft-bodied animals, has left but few traces of its existence in past time. The calcareous integumentary plates and spicules of Sea-cucumbers are, however, by no means absolutely unknown in the fossil condition, ranging from the Carboniferous onwards. The shield of *Psolus* has also been detected in Post-tertiary deposits in Bute.

LITERATURE.

GENERAL WORKS.

1. "Klassen und Ordnungen des Thier-Reichs," vol. ii. 'Strahlenthiere.' Bronn. 1860.
2. "A History of British Star-fishes and other Animals of the Class Echinodermata." Edward Forbes. 1841.
3. "Grundriss der Vergleichenden Anatomie." Gegenbaur. 1874.

4. "Die Larven und Metamorphosen der Echinodermen." J. Müller. 'Abhandl. Berlin Akad.' 1848-55.
5. Article "Echinodermata." Sharpey. Todd's 'Cyclopædia of Anatomy and Physiology.' 1839.
6. "Anatomie der Rohren-Holothurie," &c. Tiedemann. 1820.
7. "Morphologische Studien an Echinodermen." H. Ludwig. 'Zeitschr. f. Wiss. Zool.,' vols. xxviii.-xxxi.
8. "Beiträge zur Anatomie der Echinodermen." R. Teuscher. 'Jenaische Zeitschr.,' vol. x.
9. "Peculiarities in the Mode of Propagation of certain Echinoderms of the Southern Seas." Wyville Thomson. 'Journ. Linn. Soc.,' vol. xiii. 1876.

ECHINOIDEA.

10. "Monographies d'Echinodermes vivants et fossiles." Louis Agassiz. 1838-41.
11. "Catalogue raisonné des familles, des genres, et des espèces de la classe des Echinodermes." Louis Agassiz and Desor. 1847.
12. "Revision of the Echini." Alexander Agassiz. 'Memoirs of the Museum of Comparative Zoology at Harvard,' vol. iii. 1872-74.
13. "Monograph of the British Fossil Echinodermata." Thomas Wright. 'Palæontographical Society.'
14. "Monograph of the Echinodermata of the British Tertiaries." Edward Forbes. 'Palæontographical Society.'
15. "Paléontologie Française, Terrains Crétacés," tom. vi. and vii. 'Echinodermes.' A. D'Orbigny and G. Cotteau. 1856-57 and 1861-67.
16. "Synopsis des Echinides fossiles." E. Desor. 1855-59.
17. "Études sur les Echinoïdes." S. Lovén. 1874.
18. "Recherches sur l'appareil circulatoire des Oursins." Perrier. 'Arch. de Zool. Exper. et Gen.,' vol. iv. 1876.

ASTEROIDEA AND OPHIUROIDEA.

19. "System der Asteriaden." Müller and Troschel. 1843.
20. "British Fossil Echinodermata." 'The Asteroidea.' Thomas Wright. 'Palæontographical Society.'
21. "Ophiuridæ and Astrophytidæ." Theodore Lyman. 'Illustrated Catalogue of the Museum of Comparative Zoology at Harvard.' 1865.
22. "Ueber die Larven und die Metamorphosen der Ophiuren." J. Müller. 'Abhandl. Berlin Akad.' 1846. (See also several of the works mentioned under the head of "General works." As regards the development of the Asteroids and Ophiuroids, the English student may consult Professor Huxley's "Report upon the Researches of Professor Müller into the Anatomy and Development of Echinoderms," in the 'Annals of Natural History,' ser. 2, vol. viii. 1851; or Packard's 'Life-Histories of Animals.')
23. "Beiträge zur Anatomie und Histologie der Asterien und Ophiuren." Lange. 'Morphologisches Jahrb.,' vol ii.
24. "Additamenta ad historian Ophiuridarum." Lütken. 1859.
25. "North American Star-fishes." A. Agassiz. 1877.

CRINOIDEA.

26. "A Natural History of the Crinoidea," &c. J. S. Miller. 1821.
27. "Memoir on the Pentacrinus Europæus." J. V. Thompson. 1827.

28. "Ueber den Pentacrinus caput-Medusæ." J. Müller. 1843.
29. "Recherches sur les Crinoides du terrain carbonifère de la Belgique." De Koninck and Le Hon. 1854.
30. "Development of Comatula." Sir Wyville Thomson. 'Phil. Trans.' 1865.
31. "The Depths of the Sea." Sir Wyville Thomson. 1873.
32. "Notice of new living Crinoids belonging to the Apiocrinidæ." Sir Wyville Thomson. 'Journ. Linn. Soc.,' vol. xiii. 1876.
33. "On the Structure, Physiology, and Development of Antedon rosaceus." Dr W. B. Carpenter. 'Proc. Roy. Soc.' 1876.
34. "Anatomy, Physiology, and Development of Comatula." Dr W. B. Carpenter. 'Phil. Trans.' 1866.
35. "The Crinoidea of the Lower Silurian Rocks of Canada." E. Billings. 'Figures and Descriptions of Canadian Organic Remains,' Decade iv. 1859.
36. "Mémoires pour servir à la connaissance des Crinoides vivants." M. Sars. 1868.
37. "Anatomy of the Arms of Crinoids." 'Journ. Anat. and Phys.,' vols. x. and xi. P. H. Carpenter.
38. "Anatomy of Pentacrinus and Rhizocrinus." 'Journ. Anat. and Phys.,' vol. xii. P. H. Carpenter.
39. "On the Genus Actinometra." 'Trans. Linn. Soc.' 1877. P. H. Carpenter.
40. "On the Oral and Apical Systems of Echinoderms." 'Quart. Journ. Micro. Sci.,' vol. xviii. P. H. Carpenter.
41. "Entwickelungs-Geschichte der Comatula Mediterranea." 'Arch. f. Mikr. Anat.,' vol. xiii. 1876. A. Götte.

CYSTOIDEA.

42. "On the Cystidea of the Lower Silurian Rocks of Canada." E. Billings. 'Figures and Descriptions of Canadian Organic Remains,' Decade iii. 1858.
43. "Notes on the Structure of the Crinoidea, Cystidea, and Blastoidea." E. Billings. 'Palæozoic Fossils,' vol. ii. 1874.
44. "Ueber Cystideen." Von Buch. 1845. (Translated in 'Quart. Journ. Geol. Soc. Lond.' 1845.)

BLASTOIDEA.

45. "Monographie der fossilen Krinoideen-Familie der Blastoideen." Ferdinand Roemer. 1851.
(See also the works by Billings quoted above.)

HOLOTHUROIDEA.

46. "Forms of Animal Life." G. Rolleston. 1870. (For anatomy of *Cucumaria pentactes*, pp. 145-158.)
47. "Reisen im Archipel der Philippinen." C. Semper. 1868.
48. "Beiträge zur Anatomie und Systematik der Holothurien." 'Zeitschr. f. Wiss. Zool.' E. Selenka. 1867-68.

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ANNULOSA.

CHAPTER XXIII.

1. GENERAL CHARACTERS OF THE ANNULOSA. 2. DIVISIONS OF ANNULOSA. 3. GENERAL CHARACTERS OF THE SCOLECIDA. 4. CHARACTERS OF THE TÆNIADA.

SUB-KINGDOM ANNULOSA.—The Annulose animals are characterised by the possession of *a body which is usually more or less elongated, and is always bilaterally symmetrical, instead of being radially disposed.* Very *commonly the body is divided into similar* (*homonomous*) *segments, which may be definite or indefinite, and are arranged along an antero-posterior axis. Lateral appendages may be absent or present, and when present, are symmetrically disposed. A nervous system is present, and consists of one or two ganglia placed in the anterior part of the body, or of a ventrally-placed double gangliated chain.*

The association of the *Scolecida* with the normal Annulose animals renders necessary an exceedingly general, and therefore correspondingly vague, definition of the sub-kingdom *Annulosa.* The sub-kingdom may, however, be divided into the following three primary sections, each of which admits of being characterised in a sufficiently definite manner:—

I. *Scolecida.*—This division includes the parasitic worms (*Entozoa*), the Wheel-animalcules, and some allied forms, and is characterised by having an elongated or a flattened body, which may have an annulated integument, but which is not at all, or but imperfectly segmented. A water-vascular system is present, but is not concerned with locomotion. There is no true blood-vascular system, and the nervous system consists of one or two cephalic ganglia, and never has the form of a gangliated ventral chain. Lateral appendages are almost universally wanting.

The *Scolecida* were formerly placed by Huxley along with the *Echinodermata* in a special sub-kingdom (*Annuloida*); and no doubt can be entertained as to the reality of the relationships between these two groups of animals. On the other hand, many and close points of affinity unite the higher *Scolecida* with the Ringed Worms (*Annelida*); and many systematists unite the *Scolecida* and *Anarthropoda* in a common sub-kingdom, to which they restrict the Linnean name of *Vermes*.

II. ANARTHROPODA.—This division includes the Spoon Worms (*Gephyrea*), the Ringed Worms (*Annelida*), and the Arrow Worms (*Chætognatha*), and is characterised by the fact that the body is composed of a number (often indefinite) of similar or nearly similar segments arranged longitudinally. A "pseudo-hæmal" system of vessels is generally present. The nervous system is placed ventrally, and consists typically of a double chain of ganglia, united by longitudinal commissures, and forming an œsophageal collar. Cilia are generally developed. Lateral locomotive appendages are usually present, but are never jointed or articulated to the body.

III. ARTHROPODA.—This division includes the Crustaceans, (*Crustacea*), the Spiders, Scorpions, &c. (*Arachnida*), the Centipedes and their allies (*Myriapoda*), and the Insects (*Insecta*). The body (fig. 112) is composed of a series (usually definite) of distinct rings or "somites," arranged along a longitudinal axis. A true blood-vascular system is normally present, and the heart is placed dorsally. The nervous system consists primitively of a double chain of ganglia, placed ventrally, and traversed anteriorly by the œsophagus. Limbs are almost always present, and are jointed and articulated to the body. The integument is more or less extensively hardened by the deposition in it of chitine, with or without salts of lime; and ciliated epithelium is not developed.

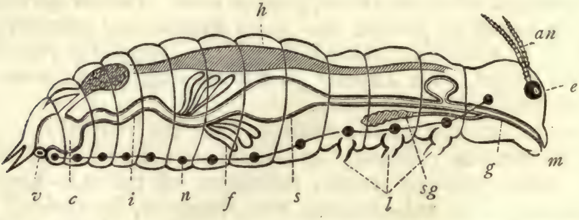

Fig. 112.—Diagram of the anatomy of an insect. *an* Antennæ; *e* Eye; *m* Mouth; *g* Gullet; *sg* Salivary gland; *s* Stomach; *f* Tubes supposed to represent the kidneys; *i* Intestine; *c* Chamber (cloaca) into which the intestine opens; *v* Vent; *h* Heart; *n* Nervous system; *l* Bases of the legs.

The Scolecida.

The name of *Scolecida* was proposed by Professor Huxley * for the reception of the *Rotifera*, the *Turbellaria*, the *Trematoda*, the *Tæniada*, the *Nematoidea*, the *Acanthocephala*, and the *Gordiacea*. Of these the *Rotifera* stand alone; whilst the *Turbellaria*, *Trematoda*, and *Tæniada* constitute the old division of the *Platyelmia* (Flat Worms); and the *Nematoidea*, *Acanthocephala*, and *Gordiacea* make up the old *Nematelmia* (Round Worms or Thread-worms). For some purposes these old divisions are sufficiently convenient to be retained, though they are of little scientific value. The term *Entozoa* has acquired such a general currency that it is necessarily employed occasionally, but it has been used in such widely different senses by different writers, that it would be almost better to discard it altogether. It certainly cannot be used as synonymous with *Scolecida*, many of these not being parasitic at all. It will therefore be employed here, in a restricted sense, to designate those orders of the *Scolecida* which are internal parasites, comprising the *Trematoda*, *Tæniada*, *Nematoidea* (in part), *Acanthocephala*, and *Gordiacea*. The *Turbellaria* and *Rotifera*, with a section of the *Nematoidea*, lead a free existence, and are not parasitic within other animals.

The *Scolecida* are defined by the possession of a "water-vascular system," consisting of a "remarkable set of vessels which communicate with the exterior by one or more apertures situated upon the surface of the body, and branch out, more or less extensively, into its substance" (Huxley). No proper vascular apparatus is present, and the nervous system (when present) "consists of one or two closely approximated ganglia." The body is not segmented, or but imperfectly so, and lateral appendages are absent in all except certain of the Rotifers. The habits and mode of life of the different members of the *Scolecida* are so different, that no other character, save the above, can be predicated which would be common to the entire group, and would not be shared by some other allied division. The most important morphological feature by which the *Scolecida* are separated from the *Annelida*, is that they are destitute of the ventral gangliated nerve-chain which is so characteristic of the latter group.

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* More recently ('A Manual of the Anatomy of Invertebrated Animals,' 1877) Professor Huxley has abandoned the division of the *Scolecida*, and has separated its members into two sections (*Trichoscolices* and *Nematoscolices*).

DIVISION I. PLATYELMIA.—This section includes those *Scolecida* which possess a more or less flattened body, usually somewhat ovate in shape, and not exhibiting anything like distinct segmentation. The division includes two parasitic orders—the *Tæniada* and the *Trematoda*,—and one non-parasitic order—viz., the *Turbellaria*. A sub-order, however, of this last, the *Nemertidæ*, does not conform to the above definition; but their other characters are such as to forbid their separation.

ORDER I. TÆNIADA (*Cestoidea*).—This order comprises the internal parasites, called Tape-worms (Cestoid worms), and the old order of the "Cystic Worms" (Cystica); the latter being now known to be merely immature forms of the Tape-worms.

The *Tæniada* are Scolecids in which *the body of the adult is elongated and composed of flattened joints, the anterior extremity ("head") armed with hooklets, or suckers, or both combined. There is no mouth or alimentary canal, and the young pass through a metamorphosis. The mature animal is hermaphrodite.*

In their mature condition, the *Tæniada* (see figs. 113 and 114) are always found inhabiting the alimentary canal of some warm-blooded vertebrate animal; and they are distinguished by their great length, and by being composed of a number of flattened joints or articulations. These joints are not, however,

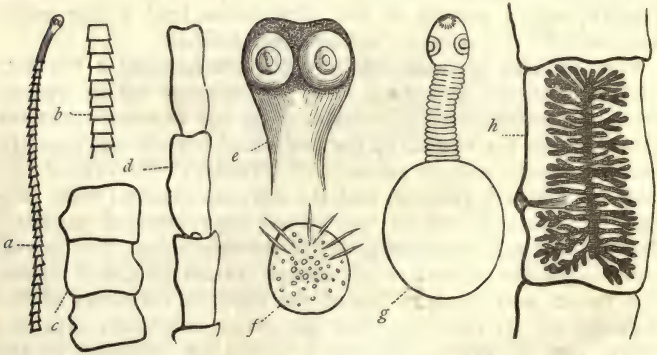

Fig. 113.—Morphology of *Tæniada*. *a* Head and a few following segments of *Tænia mediocanellata*; *b* A few segments of the same further removed from the head; *c* and *d* Segments progressively further removed from the head,—all of the natural size; *e* Head of the same, enlarged; *h* A single proglottis of the same, with its branched ovary and lateral genital pore, enlarged two diameters; *f* Embryo of *Tænia bacillaris*, with six hooklets; *g Cysticercus cellulosæ*, with its hooklets and suckers, its wrinkled neck, and its caudal vesicle, enlarged. (After Leuckart, Van Beneden, and Weinland.)

an example of true segmentation, nor do they really constitute the Tape-worm; the true animal being found in the small, rounded, anterior extremity, the so-called "head," or "nurse," whilst the joints are simply hermaphrodite generative segments, which the "head" throws off by a process of gemmation. The "head" (fig. 114, 3, and fig. 113, *e*), which constitutes the real Tape-worm, is a minute, rounded body, which is furnished with a circlet of hooks or suckers, or both, whereby the parasite is enabled to maintain its hold upon the mucous membrane of the intestines of its host. No digestive organs of any kind are present, not even a mouth; and the nutrition of the animal is entirely effected by imbibition. The nervous system consists of two small ganglia, which send filaments backwards; but there is considerable obscurity on this point, and it has been asserted that the nervous system is entirely wanting, or that there is only a single ganglion. The "water-vascular system" consists of a series of long vessels which run down each side of the body, communicating with one another at each articulation by means of a transverse vessel, and opening in the last joint into a contractile vesicle. It thus appears that all the joints are organically connected together. Whilst the "head" constitutes the real animal, it nevertheless contains no reproductive organs, and these are developed in the joints or segments (fig. 114, 3, and fig. 113, *h*), which are produced from the head posteriorly by budding. After the first joint, each new segment is intercalated between the head and the segment, or segments, already formed; so that the joints nearest the head are those latest formed, and those furthest from the head are the most mature. Each segment, when mature, contains both male and female organs of generation, and is therefore sexually perfect. To such a single segment (figs. 114, 4, and 113, *h*), the term "proglottis" is applied, from its resemblance in shape to the tip of the tongue. The ovary is a branched tube, which occupies the greater part of the proglottis, and opens, along with the efferent duct of the male organ, at a common papilla, which is perforated by an aperture, termed the "generative pore." The position of this pore varies, being placed in the centre of one of the lateral margins of the proglottis in the common Tape-worms of man (*Tænia solium* and *T. mediocanellata*), but being situated upon the flat surface of the segment in the rarer *Bothriocephalus latus*. These two elements—namely, the minute head, with its hooklets and suckers, and the aggregate of the joints, or proglottides—together compose what is commonly called a "Tape-worm," such as is found in the alimentary canal of man and of many animals. The length of this composite organism varies from less than an inch to several yards.

Singular as is the composition of the mature Tape-worm, still more extraordinary are the phenomena observed in its development, of which the following is a brief account:—

"Proglottides," or the sexually mature segments of a Tapeworm, are only produced within the alimentary canal of man, or of some other warm-blooded vertebrate. The development of the ova which are contained in the proglottides, cannot, however, be carried out in this situation; hence the comparative harmlessness of this parasite, and hence the name of "solitary worm," which is sometimes applied to it. For the production of an embryo, it is necessary that the ovum should be swallowed by some animal other than the one inhabited by the mature Tape-worm. If this does not take place, the fecundated ovum is absolutely unable to develop itself. To secure this, however, the dispersion of the ova is provided for by the expulsion of the ripe proglottides from the bowel, all their contained ova having been previously fertilised. After their discharge from the body, the proglottides, which for some time retain their vitality and possess some power of movement, decompose, and the ova are liberated (fig. 114, 1), when they are found to be covered by a capsule which protects them from all ordinary mechanical, and even chemical, agencies, which might prove injurious to them. In this stage, the embryo is often so far developed within the ovum that its head may be recognised by its possession of three pairs of siliceous hooklets. For further development, it is now necessary that the ovum be swallowed by some warm-blooded vertebrate, and should thus gain access to its alimentary canal. When this takes place, the protective capsule or covering of the microscopically minute ovum is ruptured, either mechanically during mastication, or chemically by the action of the gastric juice; and the embryo is thus liberated. The liberated embryo (fig. 113, *f*) is now called a "proscolex," and consists of a minute vesicle, which is provided with three pairs of siliceous spines, fitted for boring through the tissues of its host. Armed with these, the proscolex perforates the wall of the stomach, and may either penetrate some contiguous organ, or may gain access to some blood-vessel, and be conveyed by the blood to some part of the body, the liver being the one most likely.

Having by one of these methods reached a suitable resting-place, the proscolex now proceeds to surround itself with a cyst, and to develop a vesicle, containing fluid, from its posterior extremity, when it is called a "scolex" (fig. 114, 2, and fig. 113, *g*). In some of the *Tæniada* the scolices are called "hydatids," and it is these, also, which constituted the old order of the "Cystic Worms." When thus encysted within

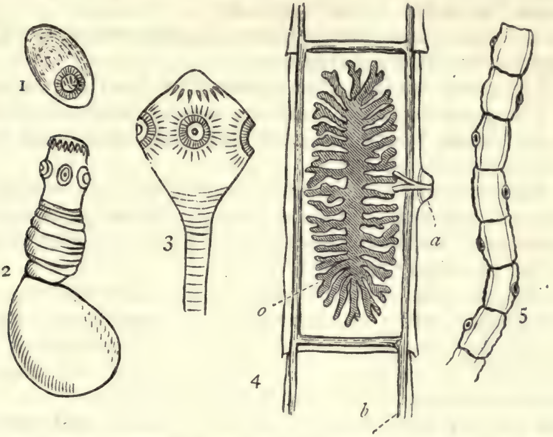

Fig. 114.—Morphology of Tæniada. 1. Ovum containing the embryo in its leathery case; 2. *Cysticercus longicollis;* 3. "Head" of the adult *Tænia solium*, enlarged, showing the hooklets and cephalic suckers; 4. A single generative joint, or proglottis, magnified, showing the dendritic ovary (*o*), the generative pore (*a*), and the water-vascular canals (*b*); 5. A portion of a Tape-worm (strobila), showing the alternate arrangement of the generative pores.

the tissues of an animal, the "scolex" consists simply of a tænioid head, with a circlet of hooklets and four "oscula" or suckers, united by a contracted neck to a vesicular body. It contains no reproductive organs, or, indeed, organs of any kind, and cannot attain any further stage of development, unless it be swallowed and be taken for the second time into the alimentary canal of a warm-blooded vertebrate. It may increase, and produce fresh scolices, but this takes place simply by a process of gemmation. The series of changes, however, whereby the scolex is converted into the "strobila," or adult tape-worm, cannot be carried out unless the scolex gain access to the alimentary canal of a warm-blooded vertebrate. In this case, the scolex attaches itself to the mucous membrane of the intestinal tube by means of its cephalic hooklets (when these are present) and suckers. The caudal vesicle now drops off, and the scolex is thus converted into the "head" of the tape-worm. Gemmation then commences from its posterior extremity, the first segments being immature. As the first-formed joints, however, are pushed further from the head by the constant intercalation of fresh articulations, they become sexually mature, thus constituting the "proglottides" of the adult tape-worm with which the cycle began. To the entire organism, with its "head" and its mature and immature joints ("proglottides"), the term "strobila" is now applied.

In the development, therefore, of the tape-worm, we have to remember the following stages:—

1. The *ovum*, set free from a generative joint or proglottis.

2. The *proscolex*, or the minute embryo which is liberated from the *ovum*, when this latter has been swallowed by any warm-blooded vertebrate.

3. The *scolex*, or the more advanced, but still sexually imperfect embryo, into which the *proscolex* develops, when it has encysted itself within the tissues of its host. (Under this head come the so-called "Cystic Worms.")

4. The *strobila*, or adult tape-worm, into which the *scolex* develops itself, when received into the alimentary canal of a warm-blooded vertebrate. The strobila is constituted by the "head," and by a number of immature and mature generative segments or joints, termed the "proglottides."

The subject will perhaps be more clearly understood by following the development of one of the common tape-worms of man—viz., the *Tænia solium*. Commencing with an individual who is already suffering from the presence of this parasite, one of the most distressing symptoms of the case is found to be the escape of the joints of the animal from the bowel. These joints are the ripe "proglottides," containing the fecundated ova. When the ova—which are microscopic in size—are liberated by the decomposition of the proglottis, they may gain access to water, or be blown about by the wind. In many ways, it is easy to understand how one of them may be swallowed by a pig. When this occurs, a "proscolex" is liberated from the ovum, and bores its way through the walls of the stomach, to become a "scolex." It now takes up its abode, generally in the muscles, in which position it was originally described as a cystic worm under the name of *Cysticercus cellulosæ* (fig. 113, *g*), constituting what is commonly known as the "measles" of the pig. In this state the scolex will continue for an indefinite period; but if a portion of "measly" pork be eaten by a man, then the scolex will develop itself into a tape-worm. The scolex fixes itself to the mucous membrane of the intestine, throws off its caudal vesicle, and commences to produce "proglottides" instead, becoming thus the "strobila" of the *Tænia solium*, with which we originally started. The other common tape-worm of man—viz., the *Tænia mediocanellata*—is derived in an exactly similar manner from the "measles" of the ox. In like manner, the tape-worm of the cat (*Tænia crassicollis*) is the mature form of the cystic worm of the mouse (*Cysticercus fasciolaris*); the *Tænia crassiceps* of the fox is derived from the *Cysticercus longicollis* of the vole (*Arvicola terrestris*); one of the tape-worms of the dog (*T. serrata*) is the fully developed form of the *Cysticercus pisiformis* of hares and rabbits; another of the tape-worms of the dog (*T. cœnurus*) is the adult of the *Cœnurus cerebralis*, which gives rise to the "staggers" of the latter animal; and another (*T. echinococcus*) spends its larval stage in the tissues of man; while *T. marginata* of the dog and wolf is the mature stage of the *Cysticercus tenuicollis* of the ruminants and of the pig. On the other hand, the embryo of the "Russian tape-worm" (*Bothriocephalus latus*) is not "cystic," but is ciliated and furnished with hooklets, whilst the scolex apparently leads an independent life in water, and its intermediary bearer (supposed by some to be a fish of the salmon tribe, or by others to be a fresh-water Annelide) is at present unknown.

Besides being liable to the attacks of various species of adult tape-worms, man is not uncommonly attacked by "scolices," or the larval forms of the tape-worms of other animals. Thus, what are professionally termed "hydatids" are really the scolices of one of the tape-worms of the dog (the *Tænia echinococcus*). The "strobila" or adult worm (fig. 115, A) is only about a quarter of an inch in length, and is singular in consisting of only four segments, including the "head." The last segment is sexually mature, and the head is furnished with hooklets and suckers. The egg gives rise, when swallowed by man, to a "proscolex," which bores its way through the walls of the stomach, and finds a lodgment in some solid organ—very commonly the liver. The primitive scolex now consists of a spherical vesicle (fig. 115, C) with a thick laminated external covering enclosing a central granular mass. This mass ultimately forms a cellular membrane lining the outer laminated envelope, and from it are developed numerous secondary "scolices," each of which is attached to the parent cyst by a pedicle, and is furnished with a crown of hooklets and four suckers, but is destitute of a caudal vesicle (fig. 115, D). In fact the parent cyst may be regarded as morphologically composed of the coalescent caudal vesicles of the contained "heads" or "*Echinococci*." The parent cyst may grow to a great size, and is filled with a clear fluid, whilst instead of producing simple "Echinococci," it may bud off numerous "brood-capsules," each of which develops in its interior a group of *Echinococcus* heads (fig. 115, B), or it may produce numerous secondary cysts, which may repeat the process, and all of which may incessantly produce "brood-capsules" and

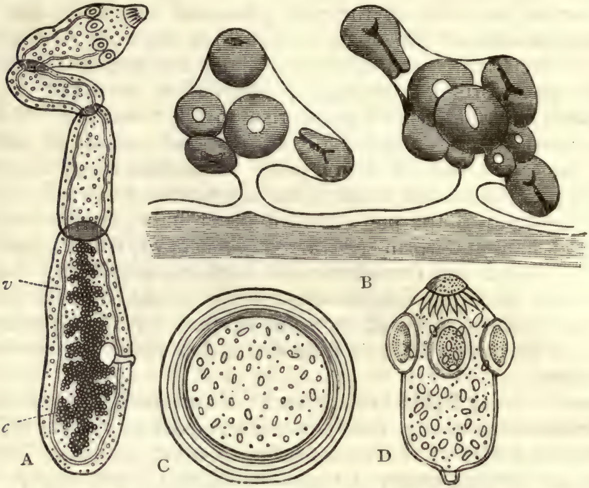

Fig. 115.—A, Sexually mature *Tænia echinococcus*, showing the head with its hooklets and suckers, and the three succeeding proglottides, the last containing the reproductive organs (enlarged); *o* Ovary; *v* Water-vessels. B, Interior of a portion of a hydatid cyst, showing the brood-capsules and included *Echinococci* (from Man). C, Young *Echinococcus*, about six weeks old, showing the thick laminated outer capsule and the inner granular contents. D, Single *Echinococcus* (from Man), showing the hooklets, suckers, contained "calcareous corpuscles," and pedicle. All the figures are enlarged. (After Spencer Cobbold and Wilson.)

"Echinococci." The disease known as "hydatids" in the human subject is, therefore, indicated by the presence in the liver or other solid organ of a strong membranous cyst, often of large dimensions, filled with a transparent watery fluid, and having attached to its interior innumerable minute secondary "scolices," or "brood-capsules," or containing daughter cysts produced by a peculiar form of gemmation. In some countries, as in Iceland, the disease is very common, and it is of a very serious character, as the growth of the tumour is apt to gravely interfere with the vital functions, or even to produce fatal results. The symptoms, of course, depend upon the position occupied by the cyst, and the importance to life of the organ affected.

CHAPTER XXIV.

TREMATODA AND TURBELLARIA.

ORDER TREMATODA.—*Leaf-like internal (sometimes external) parasites, provided with one or more ventral suckers; a mouth and alimentary canal, but no anus. No body-cavity. Integument of the adult not ciliated. Sexes generally united.* This order includes a group of animals, which, like the preceding, are parasitic, and are commonly known as "suctorial worms" or "Flukes." They inhabit various situations in different animals—mostly in birds and fishes—and they are usually flattened or roundish in shape. The body is provided with one or more suctorial pores for adhesion. An intestinal canal, with one exception, is always present, but this is simply hollowed out of the substance of the body, and does not lie in a free space, or "perivisceral cavity." The intestinal canal is often much branched, and possesses but a single external opening, which serves alike as an oral and an anal aperture, and is usually placed at the bottom of an anterior suctorial disc. A "water-vascular" system is always present, and consists of two lateral vessels which generally open on the surface by a common excretory pore. The nervous system consists of two pharyngeal ganglia. With few exceptions, the sexes are united in the same individual; and the young may be developed directly into the adult, or may pass through a complicated metamorphosis, which varies in different cases, and does not admit of description here. In many cases, the larvæ are "cercariiform," or "tailed;" and one of the early stages of their existence is often spent in the interior of fresh-water molluscs, from which they are finally transferred to their definitive host.

The "Flukes" inhabit, in their adult condition, the most varied situations. Most are internal parasites, living in the intestines or hepatic ducts of mammals, birds, or batrachians, the vitreous humour or lens of the eye, the blood-vessels, &c. A few are external parasites, living on the skin and gills of fishes, crustaceans, and other animals.

From the absence of a perivisceral cavity, the *Trematoda* were formed by Cuvier into a separate division of *Entozoa*, under the name of *Vers Intestinaux Parenchymateux*, along with the *Tæniada* and *Acanthocephala*, in which no alimentary canal is present. By Owen, for the same reason, they are included in a distinct class, under the name of *Sterelmintha.*

The *Distoma* (*Fasciola*) *hepaticum* (fig. 116, 1) may be taken as the type of the *Trematoda*. It is the common "Liver-fluke" of the sheep, and inhabits the gall-bladder or biliary ducts, giving rise to the disease known as the "rot." In form it is ovate, and flattened on its two sides, and it presents two suctorial discs, the anterior of which is perforated by the aperture of the mouth, whilst the posterior is impervious. Between the suckers is the "genital pore," at which the efferent ducts of the reproductive organs open on the exterior. A branched water-vascular system is present, and opens posteriorly by a small aperture. The alimentary canal bifurcates shortly behind the mouth, the two divisions thus produced giving off numerous lateral diverticula, and terminating posteriorly in blind extremities. The nervous system consists of two cephalic ganglia, giving off filaments both forwards and backwards. The embryo of *Distoma*, on its discharge from the egg, is inversely conical in shape, and is covered with cilia; but it appears soon to lose its cilia, and to become "cercariiform," abandoning its free aquatic life, and entering into the body of some fresh-water mollusc. When its host is eaten by some mammal the larva passes into its mature stage of development. The adult *Distoma hepaticum* is found in the sheep, ox, horse, ass, hare, deer, &c., and occasionally in man.

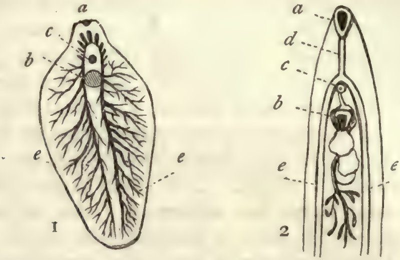

Fig. 116.—Trematoda. 1. *Distoma hepaticum*, the "Liver-fluke," showing the branched alimentary canal. 2. Anterior extremity of *Distoma lanceolatum*. *a* Anterior sucker; *b* Posterior sucker; *c* Generative pore; *d* Œsophagus; *e* Alimentary canal. (After Owen.)

In *Distoma lanceolatum* (fig. 116, 2) the intestine has not the ramose, complex character of that of *D. hepaticum*. On the other hand, the alimentary canal, after its bifurcation, is continued on each side of the body to the posterior extremity without giving off any branches on the way, and it terminates simply in blind extremities. It occurs in the liver of the ox, sheep, pig, &c., and has been likewise detected in man.

The only other Trematode which need be mentioned is the curious *Gynæcophorus* (*Bilharzia*) *hæmatobius*, which occurs abundantly in the interior of the blood-vessels of the human subject in certain regions (Egypt, South Africa, Mauritius), and has also been found in a similar situation in monkeys. The sexes are distinct in this form, the male being about half an inch, whilst the female is nearly an inch in length, and both being vermiform in shape.

ORDER TURBELLARIA.—*Leaf-like or vermiform Scolecids, rarely parasitic, with a mouth and alimentary canal, and sometimes a body-cavity; integument ciliated. Sexes united or distinct.*

The members of this order are almost all aquatic, and are all non-parasitic; thus differing entirely from the animals which compose the two preceding orders. Their external surface is always and permanently ciliated, and they never possess either suctorial discs or a circlet of cephalic hooklets. A "water-vascular system" is present, opening externally by one or more apertures, or appearing to be entirely closed in the adult (*Nemertida*). The alimentary canal is embedded in the parenchyma of the body (*Planarida*), or is freely suspended in a "perivisceral cavity" (*Nemertida*). The intestine is either straight or branched, and a distinct anal aperture may, or may not, be present. The nervous system consists of ganglia situated in the fore-part of the body, united to one another by transverse cords, and sending filaments backwards.

The *Turbellaria* are divided into two sections, termed respectively the *Planarida* and the *Nemertida*.

SUB-ORDER I. PLANARIDA.—The Planarians (fig. 117) are mostly ovoid or elliptical in shape, flattened and soft-bodied.

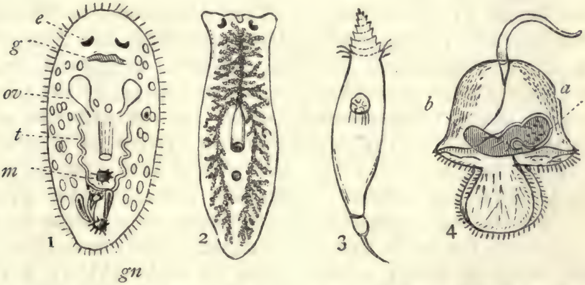

Fig. 117.—Morphology of Turbellaria. 1. *Planaria torva* (Müller): *m* Mouth; *g* Nerve-ganglion; *e* Eyes; *ov* Ovary; *t* Testis; *gn* Genital opening. 2. *Planaria lactea*, showing the branched (dendrocœl) intestine. 3. Microscopic larva of *Alaurina*, a marine Turbellarian. 4. *Pilidium*, the "pseudembryo" of a Nemertid: *a* The alimentary canal; *b* Rudiment of the Nemertid.

They are for the most part aquatic in their habits, occurring in fresh water, or on the sea-shore, but occasionally found in moist earth. The integument is abundantly provided with vibratile cilia, which subserve locomotion, and it also contains numerous cells, which have been compared to the "cnidæ," or nettle-cells, of the *Cœlenterata*. There is always a considerable portion of the body situated in front of the mouth, constituting the so-called "præ-oral region," or "prostomium;" and this is often modified into a singular protrusible and retractile organ, called the "proboscis," the exact use of which is not known. The mouth opens into a muscular pharynx, which is often evertible; and the intestine may be either straight or branched, but always terminates cæcally behind, and is never provided with an anal aperture. The "water-vascular system" communicates with the exterior by two or more contractile apertures. The nervous system consists of two ganglia, situated in front of the mouth, united by a commissure, and giving off filaments in various directions. Pigment-spots, or rudimentary eyes, from two to sixteen in number, are often present, and are always placed in the præ-oral region of the body. The male and female organs are united in the same individual, and the process of reproduction may be either sexual, by means of true ova, or non-sexual, by internal gemmation or transverse fission.

The *Planarians* have been divided into two sections, as follows:—

Section A. RHABDOCŒLA.—Intestine straight, not branched; body elongated, rounded, or oval.

Section B. DENDROCŒLA.—Intestine branched or arborescent; body flat and broad.

SUB-ORDER II. NEMERTIDA.—The *Nemertida*, or "Ribbon-worms," agree in most essential respects with the *Planarida*. They are distinguished, however, by their elongated, vermiform shape, by the presence of a distinct anus, by the possession of a distinct perivisceral cavity, by the absence of an external aperture to the water-vascular system of the adult, and by the fact that the sexes, with one or two exceptions, are distinct. The *Nemertida* further differ from the other *Platyelmia* in possessing a pseudo-hæmal system in addition to, and distinct from, the water-vascular system. The external surface of the body is richly ciliated, and is underlaid by a thick glandular cutis, beneath which are well-developed sub-cutaneous muscles. The digestive canal is ciliated internally, and consists of a muscular gullet, a sacculated stomach, and an intestine with a distinct anus. The nervous system consists of two large cephalic ganglia, united by a double commissure, and sending lateral cords backwards. The so-called "circulatory system" is composed of closed contractile vessels, sometimes containing a corpusculated fluid. "Along the median line of the dorsum lies a special muscular sheath, containing a complicated proboscis, and a highly organised corpuscular fluid, both the sheath and the proboscis passing between the commissures of the ganglia in front" (M'Intosh). The evertible and muscular sheath of the proboscis may be as long as the whole body, and the extremity of the latter may or may not be protected by one or more spines (fig. 118). The sexes are mostly in separate individuals, and the generative organs have the form of sacs placed between the muscular walls of the body and the digestive canal, and discharging their contents by lateral pores.

Reproduction takes place by the formation of true ova, by internal gemmation, or by transverse fission. In *Nemertes*, however, the egg gives rise to a larva, from which the adult is developed in a manner closely analogous to that described as characteristic of the *Echinodermata*. The larval form of *Nemertes* was described by Johannes Müller, under the name of *Pilidium* (fig. 117, 4). It is "a small helmet-shaped larva, with a long flagellum attached like a plume to the summit of the helmet, the edges and side-lobes of which are richly ciliated. A simple alimentary canal opens upon the under surface of the body between the lobes. In this condition the larva swims about freely; but, after a while, a mass of formative matter appears on one side of the alimentary canal, and elongating gradually, takes on a worm-like figure. Eventually it grows round the alimentary canal, and appropriating it, detaches itself from the *Pilidium* as a Nemertid—provided with the characteristic proboscis, and the other organs of that group of *Turbellaria*" (Huxley). Whilst some Nemertids are thus developed by internal budding from a ciliated provisional larva or "nurse," others exhibit no such phenomena, but are directly developed into the adult form, without undergoing any striking metamorphosis.

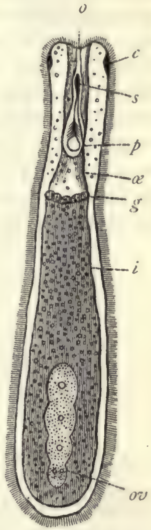

Fig. 118.—Morphology of *Nemertida*. *Prorhynchus fluviatilis*: *o* Mouth; *c* Ciliated grooves (sense-organs?); *s* Spine, attached behind to (*p*) the sac of the proboscis.; *æ* Gullet; *g* Gastric glands; *i* Intestine; *ov* Ovary. The proboscis in this form is very small. (After Gegenbaur.)

Whilst the Nemerteans undoubtedly show very close affinities to the Planarians, they are also nearly related to the *Annelida* proper, both as regards their general form and their internal structure. One of the most remarkable of the links between these two groups is to be found in *Balanoglossus*, the systematic position of which is still uncertain. This extraordinary worm is found burrowing in the sand in the Mediterranean and along the eastern coasts of North America, ranging to depths of 2500 fathoms, and possesses a flattened worm-like body, terminating in front in a protrusible hollow proboscis. The external integument is ciliated, as in the Nemerteans, and there are no setiform organs of locomotion, such as are found in so many Annelides. A water-vascular system is present; there is a well-developed alimentary canal; and the process of respiration is carried on by means of a singular branchial sac formed by a chitinous framework with ciliated apertures, somewhat similar to the "branchial sac" of an Ascidian; whilst the sexes are in different individuals. The most remarkable point, however, about *Balanoglossus* is its mode of development. The larva is a free-swimming, barrel-shaped, ciliated body, which was originally discovered by Müller, and described by him under the name of *Tornaria*, as the young of some Star-fish. In spite of its close resemblance to the larvæ of the Echinoderms, A. Agassiz has, however, succeeded in showing that *Tornaria* is really the young of *Balanoglossus*, and that it is developed into the adult by a rapid change, not accompanied by any absorption, or casting off, of any portion of the original larva.

The Nemerteans are mostly marine in their distribution, a few forms inhabiting fresh water, and two (the *Tetrastemmæ* of the Bermudas and Philippine Islands) being found in moist places on land. They are found from the arctic seas to the equator, most of them being littoral in their habits, though some live at considerable depths. Recently, Mr Moseley has described a peculiar group of Nemerteans under the name of *Pelagonemertidæ*, which are pelagic in their habits. These oceanic forms have a broad, gelatinous, flattened body, and a ramified digestive tract, and thus make a near approach to the dendrocœlous Planarians. No certain remains of Nemertids are known to occur in the fossil state, though some obscure remains have been referred to this group.

CHAPTER XXV.

NEMATELMIA.

1. Acanthocephala. 2. Gordiacea. 3. Nematoda.

Division II. Nematelmia.—This section may be considered as comprising those Scolecids in which the body has an elongated and cylindrical shape. Strictly speaking, it should include the *Nemertida*, but the division is not founded upon anatomical characters, and is employed here simply for convenience. Most of the *Nematelmia* possess an annulated integument; but there is no true segmentation, and there are rarely any locomotive appendages attached to the body. The majority are unisexual, and parasitic during the whole or a part of their existence. Three orders are comprised in this division—viz., the *Acanthocephala*, the *Gordiacea*, and the *Nematoda*.

Order I. Acanthocephala.—*Vermiform internal parasites, without mouth or alimentary canal, and having an anterior protrusible proboscis armed with recurved hooks. Sexes distinct.*

The *Acanthocephala* are entirely parasitic, vermiform in shape, and devoid of any mouth or alimentary canal. The front end of the body (fig. 119, *p*) is developed into a retractile proboscis, which is covered with tranverse rows of recurved hooks, and by means of which the parasite attaches itself to the wall of the intestine of its host. The integument (*c c*) is highly muscular, and the proboscis is contained within a strong muscular sheath, and can be retracted by special muscular bands (*m m*). At the base of the proboscis is placed a single nervous ganglion, and its hinder extremity is prolonged into *l*, the so-called "ligamentum suspensorium," a fibrous band, which supports the generative organs. The sexes are in different individuals. The water-vascular system is in the form of subcutaneous reticulated canals which are connected with two saccular organs or "lemnisci" (*b b*), placed on each side of the base of the proboscis, but the vessels of this system do not appear to communicate with the exterior.

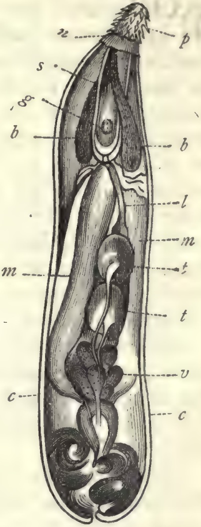

Fig. 119.—Morphology of *Acanthocephala*. Male of *Echinorhynchus angustatus*, enlarged about twelve times; *p* Proboscis; *n* Neck; *s* Muscular sheath of the proboscis; *g* Ganglion; *b b* "Lemnisci," sacs connected with the water-vascular system; *l* Ligamentum suspensorium; *m m* Retractor muscles of the proboscis; *t t* Testes; *v* Vesicula seminalis; *c c* Integument. (After Leuckart.)

The order *Acanthocephala* includes only one genus, namely, *Echinorhynchus*, the genus *Koleops* being doubtfully referred here. All the *Echinorhynchi* inhabit in their adult condition the intestines of fishes, birds, or mammals, and they pass through a metamorphosis. The eggs are swallowed by crustaceans or insects, and give exit to free vermiform embryos, armed with hooks. These burrow out of the intestine of their host and encyst themselves in its tissues, not becoming finally developed till their bearers may be eaten by some vertebrate animal. Thus, the embryos of *Echinorhynchus gigas* of the pig inhabit the larvæ of the cockchafer; whilst those of *E. angustatus*, of Cyprinoid fishes, live in the interior of fresh-water Crustaceans.

ORDER II. GORDIACEA.—*Vermiform Scolecida, parasitic in insects during a portion of their existence. An imperfectly developed alimentary canal or none. Water-vascular system rudimentary or absent. Sexes distinct.*

The *Gordiacea*, or "Hair-worms," are thread-like Scolecids, often singularly like hairs in appearance, which live in the interior of various insects during part of their life. The digestive system is imperfect, an anal aperture being universally wanting. In *Mermis*, the gullet ends in a blind sac; in *Gordius*, the digestive tube opens into the body-cavity; and in *Sphærularia*, the mouth appears to be wanting. The sexes are in different individuals. In *Gordius* itself, the embryo is free and aquatic, having a retractile snout armed with hooklets, by means of which it, after a time, bores its way into the tissues of some water-insect, in which it encysts itself. The sexually-mature worms are found in the interior of *Orthoptera* or *Neuroptera;* but they leave their hosts and betake themselves again to an aquatic existence for the purpose of laying their eggs. The adult *Mermis* is found principally in *Lepidoptera;* whilst *Sphærularia* inhabits the body-cavity of Bumblebees. A form of the *Gordiacea* has also been found at great depths in the ocean, coiled up beneath the carapace of shrimps (Willemöes-Suhm).

ORDER III. NEMATODA (or *Nematoidea*).—*Cylindrical vermiform Scolecids, sometimes parasitic, sometimes free; integument not ciliated; a well-developed alimentary canal, with a mouth and anus, suspended freely in a body-cavity; sexes distinct, or rarely united.*

The *Nematoda* comprise the so-called "Thread-worms" and "Round-worms," and, as their various names imply, possess a rounded and worm-shaped body (fig. 120, *a*), sometimes of great length. The cuticle is chitinous and porous; and there is generally a distinct annulation, though no true segmentation exists. The alimentary system is well developed, the mouth being anterior, and usually furnished with papillæ (fig. 120, *c*). The gullet opens into a muscular stomach, from which an intestine conducts to a ventrally or terminally placed anus; the whole digestive tube being freely suspended in a body-cavity, which is filled with a sparsely corpusculated fluid. There is a water-vascular system, composed of lateral tubes, which open on the surface by a ventrally-placed pore. The nervous system is in the form of a ganglionic ring, surrounding the gullet, and sending filaments backwards and forwards. The sexes are mostly distinct, the external openings of the reproductive organs being placed near the anus. The males are usually less frequently met with and of smaller size than the females, and they possess a single or double spicular penis (fig. 120, *b*). Metamorphosis may or may not occur during development.

As before said, most of the *Nematoda* are internal parasites, inhabiting the alimentary canal, the pulmonary tubes, or the areolar tissue, in man and in many other vertebrate animals; but a large section of the order are of a permanently free habit of existence.

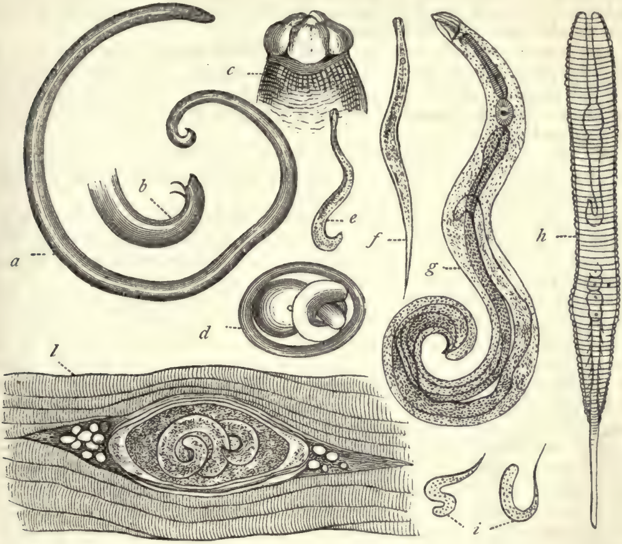

Fig. 120.—Morphology of Nematoda. *a Ascaris lumbricoides*, male, reduced in size; *b* Hinder extremity of the same, with the reproductive spicula, enlarged; *c* Head of the same enlarged, showing the tubercles round the mouth; *d* Ovum of the same, highly magnified, with the fully-developed worm in its interior; *e* Male of *Oxyuris vermicularis*, five times the natural size; *f* Female of the same, similarly enlarged; *g* Male of the same, highly magnified; *h* Embryo of *Dracunculus*, magnified 500 diameters; *i* Embryos of the same, magnified 60 diameters; *l* A single *Trichina*, encapsuled in the muscles, highly magnified. (Chiefly after Leuckart, Spencer Cobbold, and Bastian.)

Amongst the more important members of the parasitic section of the *Nematoda* may be mentioned the *Ascaris lumbricoides*, the *Oxyuris vermicularis*, the *Trichocephalus dispar*, the *Sclerostoma duodenale*, the *Dracunculus medinensis*, and the *Trichina spiralis*.

The *Ascaris lumbricoides*, or common Round-worm, inhabits the intestine of man, and sometimes of other mammals, especially the pig, often attaining a length of several inches. The ova are expelled with the fæces, and the embryo is developed within the ovum prior to its rupture, but not till after the lapse of several months (fig. 120, *d*). When fully formed, the embryo is about one-hundredth of an inch in length, and its development is not exactly known, though it appears to be directly transferred from river or pond water to the alimentary canal of its host. The body of the adult (fig. 120, *a*) is cylindrical, attenuated at both extremities. At the anterior extremity is a sub-triangular mouth, surrounded by three tubercles (fig. 120, *c*). The anus is situated posteriorly. The females are larger than the males, and are much more numerous. These parasites are much more common in children than in adults, and they often occur in considerable numbers. They are usually found in the small intestine, though they sometimes wander into other situations.

The *Oxyuris vermicularis*, or "small Thread-worm" (fig. 120, *e*, *f*, *g*), is a gregarious worm, which inhabits the rectum, especially of children. It is the smallest of the intestinal worms of man, its average length not being more than a quarter of an inch, but the females are much bigger than the males.

The *Trichocephalus dispar* inhabits the cæcum of man. It is from one and a half to two inches in length, and the anterior two-thirds of the body is extremely attenuated and thread-like.

The *Sclerostoma duodenale* inhabits the small intestine in the human subject, and is far from uncommon in Italy and in Egypt. It varies in size from one-third of an inch to half an inch, the females being the largest; and the symptoms to which it gives rise are often of a serious character.

The *Trichina spiralis* is a singular Nematoid, which gives rise to a painful and not uncommonly fatal train of symptoms, somewhat resembling rheumatic fever, and known as Trichiniasis. The *Trichina* is known in two different conditions, sexually immature or mature. In its sexually immature condition it inhabits the muscles, usually of the pig (the rat, however, being apparently its true host), in vast numbers, each worm (fig. 120, *l*) being coiled up in a little capsule or cyst. In this condition the worm is incapable of further development, and may remain, apparently for an indefinite period, without change, and without seeming to produce any injurious results to the animal affected. If, however, a portion of trichinatous muscle be eaten by a warm-blooded vertebrate, and so introduced into the alimentary canal, an immediate development of young *Trichinæ* is the result. The immature worms escape from their enveloping cysts, grow larger, develop sexual organs, and give birth to a numerous progeny, which they produce viviparously. The young *Trichinæ* thus produced perforate the walls of the alimentary canal, and, after working their way amongst the muscles, become encysted. If the animal in which these changes go on has sufficient vitality to bear up under the severe symptoms which are produced by the migration of the *Trichinæ*, he is now safe; since they cannot become sexually mature, or develop themselves further, until again transferred to the alimentary canal of some other animal.

The Guinea-worm (*Dracunculus* or *Filaria medinensis*) is a Nematode worm, which inhabits, during one stage of its existence, the cellular tissue of the human body, generally attacking the legs, and often attaining a length of several feet. All known specimens of this parasite are impregnated females, containing a large number of young. The worm remains embedded in the body, in a more or less quiescent condition, for a year or more, at the end of which time it seeks the surface, in order to get rid of its young. No external aperture to the genital organs has hitherto been proved to exist, and it seems possible that the young are produced within the body of the parent by a process of internal gemmation. The young *Filaria* (fig. 120, *h* and *i*) consists of a vermiform body, terminating in a hair-like tail; and when set free from the parent, its further development probably takes place in water, when it is believed to be converted into one of the "Tank-worms" so common in India. In this condition, it is possible, as some believe, that sexual organs are developed, and that the females are impregnated. The young worm is believed to pass the intermediate portion of its life in the interior of fresh-water Crustaceans (*Cyclops*), but how it gains access to the cellular tissue of man is still unknown. According to Dr Bastian, however, it appears probable that the Guinea-worm "is a parasite only accidentally, and that it and its parents were originally free Nematoids."

In addition to the above-mentioned forms, it may be noted that minute parasitic Nematoids are not uncommonly found, sometimes in vast numbers, in the blood of various animals, including the dog, man himself, and various birds. Some of these hæmatozoa are embryonic, others appear to be mature, and they may or may not give rise by their presence to appreciable morbid symptoms. The origin of these hæmatozoa, their development, and the mode in which they are introduced into the blood, are subjects, for the most part, still shrouded in obscurity. The most remarkable species is the *Filaria sanguinis-hominis*, which in its immature state inhabits the blood of man in intertropical regions, its presence being commonly associated with chyluria, hæmaturia, and other morbid affections.

The second section of the *Nematoda* comprises worms which are not at any time parasitic, but which are permanently free. These "free Nematoids" (fig. 121) constitute the family of the *Anguillulidæ*, of which about two hundred species have been already described, mostly inhabiting fresh water or the shores of the sea. They resemble the parasitic Nematoids in all the essential features of their anatomy, but they differ in often possessing pigment-spots, or rudimentary eyes, in being mostly provided with a terminal sucker, and in bringing forth comparatively few ova at a time; the dangers to which the young are exposed being much less than in the parasitic forms. Amongst the more familiar free Nematoids are the Vinegar Eel (*Anguillula aceti*, fig. 122, A) and the *Tylenchus* (or *Vibrio*) *tritici*, which produces a sort of excrescence or gall upon the ear of wheat, causing the disease known to farmers as the "Purples," or "Ear Cockle."

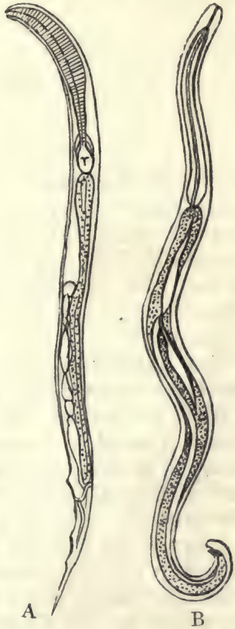

Fig. 121.—Free Nematoids. A, *Anguillula aceti*; B, *Dorylaimus stagnalis*. Magnified. (After Bastian.)

The parasitic and free Nematoids are connected together by an *Ascaris* (*A. nigrovenosa*), which in succeeding generations is alternately free and parasitic. This *Ascaris* has long been known as inhabiting the lungs of the frog, but it has been shown by Mecznikow that "the young of this animal become real free Nematoids; for, after passing from the intestine of the frog into damp earth or mud, they grow rapidly, and actually develop in the course of a few days, whilst still in this external medium, into sexually mature animals. Young, differing somewhat in external characters from their parents, are soon produced by them, and these attain merely a certain stage of development whilst in the moist earth, arriving at sexual maturity only after they have become parasites, and are ensconced in the lung of the frog" (Bastian). This extraordinary history is rendered still more remarkable, if it should be proved that the young of the parasitic forms of this *Ascaris* are produced by a process of parthenogenesis; and this seems to be highly probable, since none of the individuals which are found as parasites are males, but are universally females.

CHAPTER XXVI.

ROTIFERA.

SUB-CLASS ROTIFERA (*Rotatoria*).—The *Rotifera*, or "Wheel-animalcules," constitute a very natural group, the exact position of which has been a good deal disputed, and is still doubtful. They are looked upon here as a distinct division of the *Scolecida ;* but they are very frequently placed with the *Annelida* amongst the next division of the *Annulosa* (*Anarthropoda*).

The *Rotifera* are *minute animals, never parasitic, inhabiting water, and usually provided with an anterior ciliated disc, capable of inversion and eversion. In the females there is a distinct mouth, intestinal canal, and anus. A nervous system is also present, consisting of ganglia, situated near the anterior extremity of the body, and sending filaments backwards. A water-vascular system is also present. The sexes are distinct.*

Most of the *Rotifera* are entirely invisible to the naked eye, and they are all extremely minute, none of them attaining a greater length than 1-36th of an inch. Nevertheless, as remarked by Mr Gosse, "so elegant are their outlines, so brilliantly translucent their texture, so complex and yet so patent their organisation, so curious their locomotive wheels, so unique their apparatus for mastication, so graceful, so vigorous, so fleet, and so marked with apparent intelligence, their movements, so various their forms and types of structure," that they form one of the most interesting departments of zoological and microscopical study. They are all aquatic in their habits, and in the great majority of cases are free-swimming animals, some, however, being permanently fixed, as is the case with *Stephanoceros*, *Melicerta* (fig. 122, B), and *Floscularia*. They are usually simple, but are occasionally composite, forming colonies, as in *Megalotrocha*. As a rule, the male and female *Rotifera* differ greatly from one another, the males being smaller than the females, destitute of any masticatory or digestive apparatus, and more or less closely resembling the young form of the species. The most characteristic organ in the great majority of the *Rotifera*, is the so-called "wheel-organ," or "trochal disc," which is always situated at the cephalic or distal end of the body, and consists of a retractile disc, surrounded by a circlet of cilia, which, when in action, vibrate so rapidly as to produce the illusory impression that the entire disc is rotating.

The disc, which carries the cilia, is capable of eversion and inversion, and may be circular, reniform, bilobed, four-lobed, or divided into several lobes. It serves the purpose of locomotion in the free-swimming forms, acting somewhat like the propeller of a screw-steamer; and in all it serves to produce currents in the water, which convey the food to the mouth.

In *Chætonotus*, and some other forms (*Gastrotricha*), there is no true wheel-organ, capable of protrusion and retraction, but the cilia are variously disposed over the surface of the body. The *Chætonoti* or Hairy-backed Animalcules have no jaws, and have the ventral surface of the body clothed with cilia. They have often been placed in the *Turbellaria*, but there seem to be good reasons for regarding them as an aberrant group of *Rotatoria*. *Balatro* and *Apsilus* are non-ciliated in the adult condition.

The proximal extremity of the body in the free forms terminates in a caudal process, or "foot," sometimes telescopic, which ends in a suctorial disc, or in a pair of diverging "toes," which act as a pair of forceps (fig. 122, A).

The mouth usually opens into a pharynx, or "buccal funnel," which is generally provided with a muscular coat, constituting the "mastax" or "pharyngeal bulb," and which generally contains a very complicated masticatory apparatus.* The parts of this apparatus are horny, and are believed by Mr Gosse to be homologous with the parts of the mouth in insects. In the females of almost all known species of *Rotifera* the intestinal canal is a more or less simple tube, extending through a well-developed perivisceral cavity, and terminating posteriorly in a dilatation, or "cloaca," which forms the common outlet for the digestive, generative, and water-vascular systems.

In both sexes there is a well-developed water-vascular system, usually consisting of the following parts:—

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* The lower jaws, or "incus," consist of a fixed portion, the "fulcrum," to which are attached two movable blades—the "rami." The upper jaws, or "mallei," consist each of a handle, or "manubrium," to which is hinged a toothed blade, or "uncus."

In the hinder part of the body, close to the cloaca, and opening into it, is a sac or vesicle, which is termed the "contractile bladder," and exhibits rhythmical contractions and dilatations. From the contractile bladder proceed two tubes—"the respiratory tubes"—which pass forwards along the sides of the body, and terminate anteriorly in a manner not quite ascertained. Attached to the sides of the respiratory tubes, in all the larger *Rotifera*, is a series of ovate or pyriform vesicles, each of which is furnished internally with a single central cilium, which is fixed to the free end of the vesicle. It is asserted, however, that these ciliated vesicles communicate internally with the perivisceral cavity with its contained corpusculated fluid. The exact function of this water-vascular system is not known, but it is most probably respiratory and excretory. Dr Leydig believes that water enters the perivisceral cavity by endosmose, where it mingles with the absorbed products of digestion, to form the so-called "chylaqueous fluid;" and that the effete fluid is excreted by the respiratory tubes, and ultimately discharged into the cloaca by the contractile bladder. Taking this view of the subject, Mr Gosse believes that the "respiratory tubes represent the kidneys, and that the bladder is a true urinary bladder;" and consequently that the "respiratory and urinary functions are in the closest relation with one another." This observer, further, finds a decided analogy between the above system in the *Rotifera* and the long and tortuous renal tubes of the *Insecta*, to which class he believes the *Rotifera* to be most nearly allied.

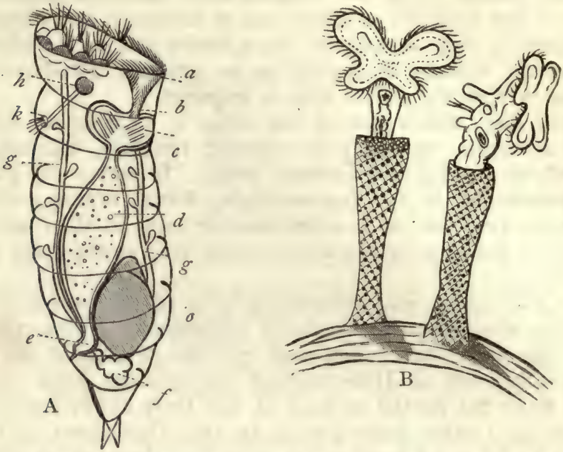

Fig. 122.—Rotifera. A, Diagrammatic representation of *Hydatina senta* (generalised from Pritchard): *a* Depression in the ciliated disc leading to the digestive canal; *b* Mouth; *c* Pharyngeal bulb or mastax, with the masticatory apparatus; *d* Stomach; *e* Cloaca; *f* Contractile bladder; *gg* Respiratory or water-vascular tubes; *h* Nerve-ganglion giving filament to ciliated pit (*k*); *o* Ovary. B, *Melicerta ringens*. (After Gosse.)

No central organ of the circulation, or heart, and no organs of respiration are present, but the perivisceral cavity is filled with a corpusculated fluid.

The nervous system of the *Rotifera* constitutes a bilobate cerebral mass, "which for its proportionate volume may compare with the brain of the highest vertebrates." It is placed anteriorly, and usually on the dorsal aspect of the body, and the eye—in the shape of a red pigment spot or spots—is invariably situated like a wart upon it. Other sense-organs, probably tactile, are often present, in the form of two knobs surmounted by tufts of bristles, placed at the back of the head. The ovaries constitute conspicuous organs in the female *Rotifera*, and in summer the eggs are produced by the females without having access to the males. Development is direct.

The muscular system of the *Rotifera* is well developed, consisting of bands which produce the various movements of the body and foot, whilst others act upon the various viscera, and others effect the movements of the jaws.

The typical group of the *Rotifera* is that of the *Notommatina* (*Hydatinea* of Ehrenberg.) In this group (fig. 123) the animals are all permanently free, and are never combined into colonies, while the integument is flexible, and the body is never encased in a tube.

Stephanoceros and *Floscularia*, on the other hand, are fixed, and are enclosed in a gelatinous tube which is secreted by the animal. *Melicerta* (fig. 122, B) inhabits a tubular case, which the animal forms for itself by means of a special organ for the purpose; whilst *Polyarthra* and *Triarthra* are protected by a stiff shell, or "lorica."

In *Triarthra* there are ensiform fins, jointed to the body by distinct shelly tubercles, and moved by powerful muscles. These natatory organs are considered by Mr Gosse to be homologous with the articulated limbs of the *Arthropoda*. Locomotive appendages are also present in *Hexarthra*, *Polyarthra*, and *Pedalion*.

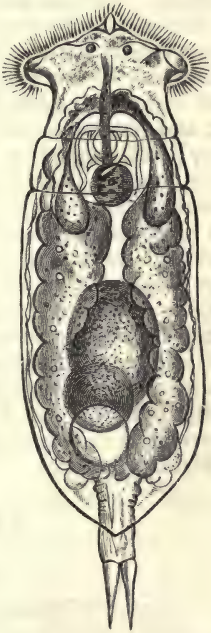

Fig. 123.—Rotifera. *Eosphora aurita*, one of the Wheel-animalcules. Enlarged about 250 diameters. (After Gosse.)

In *Asplanchna*, whilst the masticatory organs, gullet, and stomach are well developed, there is no intestine, the stomach "hanging like a globe in the centre of the body-cavity," but not communicating with the body-cavity.

As regards their distribution in space, the *Rotifera* have an almost world-wide range. The majority of the known forms are inhabitants of fresh water, but a few live in the sea.

Affinities of Rotifera.—In their external appearance the *Rotifera* approximate closely to the *Infusoria*, but the organisation of the former presents a very striking advance when compared with that of the latter. Thus, in the *Infusoria* there is no differentiated body-cavity, bounded by distinct walls, and the alimentary canal is imperfect, the digestive sac simply opening inferiorly into the diffluent sarcode of the centre of the body. Further, there are no traces of a nervous system, and the contractile vesicles, if looked upon as representing the water-vascular system, are a very rudimentary form of this apparatus. In the *Rotifera*, on the other hand, the alimentary canal forms a complete tube, having an oral and an anal aperture, and not communicating with the surrounding perivisceral cavity; and there is a well-developed nervous system, and a highly complex water-vascular system. A real affinity is found to subsist, however, between the *Rotifera* and the *Planarida*; both possessing external cilia, a nervous system, and a well-developed water-vascular apparatus, the characters of which are not dissimilar in the two groups. In the *Planarida*, however, the sexes are united in the same individual, and there is no anal aperture; whereas in the *Rotifera* the sexes are distinct, and there is a distinct anus. To the true *Arthropoda*, as already pointed out, the *Rotifera* show some points of affinity, but these are hardly sufficiently numerous or decided to warrant the removal of the group from the *Scolecida* to beside the higher *Annulosa*.

LITERATURE.

General Works.

1. "Entozoa: an Introduction to the Study of Helminthology." T. Spencer Cobbold. 1864.
2. "Entozoa: being a Supplement to the Introduction to the Study of Helminthology." T. Spencer Cobbold. 1869.
3. "The Internal Parasites of our Domesticated Animals." T. Spencer Cobbold. 1874.
4. "Parasites." T. Spencer Cobbold. 1879.
5. "Die Menschlichen Parasiten." Rudolf Leuckart. 1863 and 1876.
6. "On Animal and Vegetable Parasites of the Human Body." Küchenmeister. Translated from the German by Dr E. Lankester. 1857.
7. "Catalogue of the Species of Entozoa, or Intestinal Worms, contained in the Collection of the British Museum." W. Baird. 1853.
8. "The Science and Practice of Medicine." W. Aitken. (Vol. ii. contains an excellent summary of the chief facts concerning the Entozoa of Man.)
9. "Synopsis of Entozoa." Leidy. 1856.
10. "Elements of Medical Zoology." Moquin-Tandon. Translated from the French by Dr Hulme. 1861.

11. Article "Entozoa." Owen. Todd's 'Cyclopædia of Anatomy and Physiology.' 1839.
12. "Helminthology." Von Siebold. Translated from the German by Mr Busk. 1847.
13. "Mémoire sur les Vers Intestinaux." Van Beneden. 1858.
14. "Catalogue of the Specimens of Entozoa in the Museum of the Royal College of Surgeons of England." T. Spencer Cobbold. 1866.

TÆNIADA.

15. "Tapeworms; their Sources, Nature, and Treatment." T. Spencer Cobbold. 1867.
16. "Les Vers Cestöides." Van Beneden. 1858.
17. "Ueber die Band- und Blasen-würmer." Von Siebold. 1854. Translated from the German by Prof. Huxley. 1857.
18. "An Essay on the Tapeworms of Man." Weinland. 1858.
19. "On the Anatomy and Development of the Cystic Entozoa." Prof. Goodsir and H. Goodsir. 'Anatomical and Pathological Observations.' 1845.
20. "On the Anatomy and Development of *Echinococcus veterinorum.*" T. H. Huxley. 'Proc. Zool. Soc.' 1852.
21. "On the Structure and Development of *Cysticercus cellulosæ.*" G. Rainey. 'Phil. Trans.' 1857.

TREMATODA.

22. "Entwurf einer systematischen und speciellen Beschreibung der Plattwürmer." S. Oersted. 1844.
23. "Trematoden-larven und Trematoden." Pagenstecher. 1857.
24. "Mémoire sur les Vers Intestinaux." Van Beneden. 1858.
25. "On the Alternation of Generations." Steenstrup. Translated by Mr Busk. 1845.

TURBELLARIA.

26. "Catalogue of the British Non-Parasitical Worms in the Collection of the British Museum." Dr Johnston. 1865.
27. "Beiträge zur Naturgeschichte der Turbellarien." Max Schultze. 1861.
28. "Symbolæ Physicæ." Ehrenberg. 1831.
29. "Untersuchungen über niedere Seethiere." Leuckart and Pagenstecher. 'Müller's Archiv.' 1858.
30. "Monograph of the British Annelides. Part I.—The Nemerteans." Dr. W. C. M'Intosh. 'Ray Society.' 1873 and 1874.
31. "Studien an Turbellarien." Minot. 'Arbeiten aus dem Zool. Instit. in Würzburg,' vol. iii.

ACANTHOCEPHALA.

32. "On the Acanthocephali." R. Leuckart. Translated from the German. 'Annals of Nat. Hist.' 1863.
33. "On the Development of *Echinorhynchus gigas.*" Schneider. Translated from the German in 'Annals of Nat. Hist.' 1871.

GORDIACEA.

34. "On *Sphærularia Bombi.*" Sir John Lubbock. 'Natural History Review.' 1861 and 1864.

NEMATODA.

35. "On the Anatomy and Physiology of the Nematoids, parasitic and free, with observations on their Zoological Position," &c. H. C. Bastian. 'Phil. Trans.' 1866.
36. "Monograph of the Anguillulidæ, or Free Nematoids, marine, land, and fresh-water, with descriptions of 100 New Species." H. C. Bastian. 'Linnean Trans.' 1865.
37. "The Microscopic Organisms found in the Blood of Man and Animals, and their Relations to Disease." Lewis. 1879.
38. "The Life-History of Filaria Bancrofti," &c. T. Spencer Cobbold. 'Journ. Linn. Soc.,' vol xiv. 1878.
39. "On the Development of Filaria sanguinis-hominis, and on the Mosquito considered as a Nurse." Manson. 'Journ. Linn. Soc.,' vol. xiv. 1878.

ROTIFERA.

40. "Infusoria." Pritchard.
41. "Die Infusionsthierchen." Ehrenberg.
42. "On the Manducatory Apparatus in the Rotifera." Gosse. 'Phil. Trans.' 1856.
43. "The Crown Animalcule." Gosse. 'Popular Science Review,' vol. i. 1866.
44. "The Flower Animalcules." Gosse. 'Popular Science Review,' vol. i.
45. "The Builder Animalcules." Gosse. 'Popular Science Review,' vol. i.
46. "The Natural History of the Hairy-Backed Animalcules (*Chætonotidæ*)." Gosse. 'Intellectual Observer.' 1864.
47. "Ueber den Bau und die Systematische Stellung der Räder-Thiere." Frantz Leydig. 'Siebold and Kölliker's Zeitschrift.' 1854.
48. "*Hydatina senta.*" Cohn. 'Zeitschrift für Wiss. Zool.' 1855.
49. "Anatomy of Rotifera." Huxley. 'Trans. Micros. Soc.' 1853.
50. "On Lacinularia socialis." Huxley. 'Trans. Micros. Soc.' 1851.

CHAPTER XXVII.

ANARTHROPODA.

THE division *Anarthropoda* includes the three classes of the Spoon-worms (*Gephyrea*), the Ringed Worms (*Annelida*), and the Arrow-worms (*Chætognatha*), and constitutes the highest section of the "Vermes" of modern zoologists. The members of this division are characterised by the possession of an elongated worm-like body, which usually shows a conspicuous composition out of similar, or nearly similar, segments, which, however, are not numerically definite. The nervous system, in the typical members of the division, consists of a ventrally-placed double chain of ganglia, one pair of ganglia corresponding with each segment, the anterior pair being placed above the gullet, and all being united by longitudinal commissures. Lateral locomotive appendages are usually present, but are not composed of successive joints, nor are articulated to the body. A true blood-vascular system is not developed; but there is usually a closed system of "pseudohæmal vessels."

GEPHYREA.

CLASS I. GEPHYREA (= *Sipunculoidea*).—*Vermiform marine animals, with usually elongated bodies which may be indistinctly annulated, but are not segmented, and carry no locomotive appendages (beyond, occasionally, bristles). Ventral nerve-cords not ganglionated; sexes generally distinct; a distinct metamorphosis in development.*

The members of this class are generally known as "Spoonworms," and they form a connecting link between the *Echinodermata* and the Annelides. The body is worm-like, the integument sometimes ringed (fig. 124), but never divided into distinct segments. There are no ambulacral tube-feet, nor foot-tubercles; but there may be bristles which act as locomotive organs (as in *Echiurus*), while in *Chætoderma* calcareous spines occur in the integument. The outer layer of the integument is chitinous, and beneath the skin is a strong muscular coat of longitudinal and circular fibres. The mouth is placed at the front end of the body, and the ciliated alimentary canal terminates in an anal aperture which may occupy the hinder end of the body, or may be placed far forward on the dorsal surface. A retractile or contractile proboscis is present, and may be provided with bristles or tentacles. The intestine is convoluted, and is suspended freely in a body-cavity, which is filled with a corpusculated fluid, kept in circulation by ciliary action. A vascular ("pseudohæmal") system may be present, or in other cases is not developed. Respiration is carried on by the general surface of the body, by hollow tentacles placed round the mouth (*Sipunculus*), or by abdominal

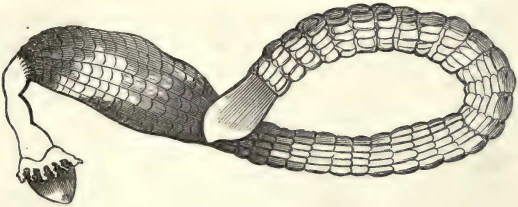

Fig. 124.—Gephyrea. *Syrinx nudus.* (After Forbes.)

organs resembling the "respiratory tree" of the Holothurians (as in *Echiurus*), the latter, however, being rather excretory than respiratory in function. The nervous system has the form of a gangliated œsophageal ring, giving off a ventral cord, which is peculiar in not having distinct ganglia developed upon it. The sexes are in different individuals (united in some species of *Sipunculus*); and the males may differ greatly from the females in form. The reproductive elements often reach the exterior by the ducts of certain ciliated sacs, which open by pores on the ventral surface of the body, and which correspond with the "segmental organs" of the Annelides.

In their development, the *Gephyrea* pass through a metamorphosis, generally of a very striking character. The larva (fig. 125) is locomotive, and swims about actively, partly by means of a ciliary ring placed round the neck, and partly by means of ciliated lobes developed on the head. In this "actinotrocha" stage the larva resembles that of the Echinoderms in many respects; whilst the ciliated cephalic lobes call to mind the trochal discs of the Rotifers. The further process of development is also strikingly similar to that characteristic of the Echinoderms, a considerable portion of the larva, including the ciliated cephalic expansion, being ultimately absorbed.

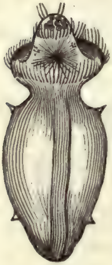

Fig. 125.—Larva of *Phascolosoma elongatum*, after development has proceeded to some extent.

The *Gephyrea* are exclusively inhabitants of the sea, mostly burrowing in the sand, or hiding in crevices in the rocks. The principal and most widely distributed genus is *Sipunculus*, the species of which often inhabit the cast-away shells of Univalves, and which ranges from the littoral zone down to a depth of 2500 fathoms.

As to their affinities, the *Gephyrea* are related, on the one hand, to the Holothurians, from which they differ in the absence of an ambulacral system,* in the fact that the integument is almost universally incapable of secreting calcareous matter, and in the absence of any traces of a radiate arrangement of the nervous system. On the other hand, they show their close relation to the true Annelides, by their general possession of a pseudohæmal system, and of "segmental organs," by the form of the nervous system, and by the resemblance of their larvæ to those of many of the Errant Ringed Worms.

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* *Sipunculus* has a system of peculiar water-vessels developed in connection with the oral tentacles, which may, perhaps, be homologous with the ambulacral vessels of the Echinoderms.

ANNELIDA.

CLASS II. ANNELIDA (= *Annulata*). The *Annelida* are vermiform animals, distinguished from the preceding by the possession of *distinct external segmentation; the nervous system is composed of a ventral, double, gangliated cord, with an œsophageal collar and præ-œsophageal ganglion.*

This class comprises elongated worm-like animals, in which the integument is always soft, and the body is more or less distinctly segmented, each segment usually corresponding with a single pair of ganglia in the ventral cord. All the segments are similar to one another except those at the anterior and posterior extremities of the body. Each segment may also be provided with a pair of lateral appendages, but these are never articulated to the body, and are never so modified in the region of the head as to be converted into masticatory organs.

In the higher *Annelida* each segment (fig. 126) consists of two arches, termed, from their position, respectively the "dorsal arc" and the "ventral arc;" and each bears two lateral processes, or "foot-tubercles" (*parapodia*), one on each side. Each "foot-tubercle" is typically double, being composed of an upper process, called the "notopodium," or "dorsal oar," and a lower process termed the "neuropodium," or "ventral oar;" but these may be fused together. The foot-tubercles,

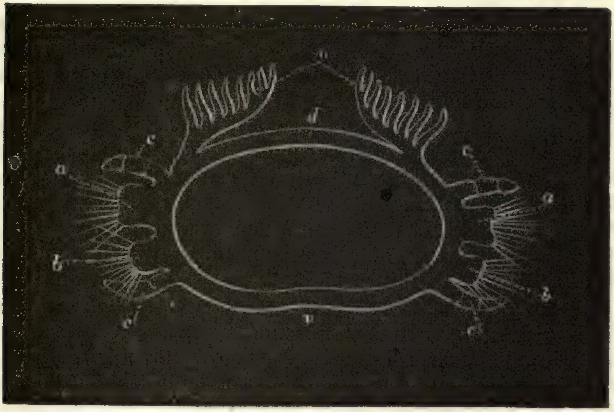

Fig. 126.—Diagrammatic transverse section of an Annelide. *d* Dorsal arc; *v* Ventral arc; *n* Branchiæ; *a* Notopodium, or dorsal oar; *b* Neuropodium, or ventral oar, both carrying setæ and a jointed cirrhus (*c*).

likewise, support bristles, or "setæ," and a soft cylindrical appendage, which is termed the "cirrhus" (fig. 126).

The number of the segments varies much, being as many as 400 in *Eunice gigantea;* and, generally, there is not a distinct head which is separable from the succeeding rings of the body. When such a distinct head appears to be present, it is not comparable with the head of the *Arthropoda*, but is really a greatly modified præ-oral region, or "prostomium," as is shown by the position of the mouth. The "prostomium" or "cephalic lobe" is placed in front of the mouth, and often carries "tentacles" above and tactile processes or "palpi" below.

The digestive system of the Annelides consists of a mouth, sometimes armed with horny jaws, a gullet, stomach, intestine, and a distinct anus. Except in the *Hirudinea*, the alimentary canal is suspended in a capacious perivisceral space, divided into compartments by more or less complete partitions. The alimentary canal is, with one exception, not convoluted, and extends straight from the mouth to the anus; but lateral diverticula are often present.

As regards the vascular system, "no Annelide ever possesses a heart comparable to the heart of a Crustacean or Insect; but a system of vessels, with more or less extensively contractile walls, containing a clear fluid, usually red or green in colour, and in some cases only corpusculated, is very generally developed, and sends prolongations into the respiratory organs, when such exist" (Huxley). This system has been termed the "pseudohæmal system," and its vessels are considered by Professor Huxley as being "extreme modifications of organs homologous with the water-vessels of the *Scolecida:*" since the perivisceral cavity, with its contained corpusculated fluid (chylaqueous fluid), is, as shown by M. de Quatrefages, the true homologue of the vascular system of Crustacea and Insects. The pseudohæmal system, therefore, of the Annelides is to be regarded as essentially respiratory in function. The pseudohæmal vessels are sometimes wanting, and in these cases respiration appears to be effected by the cilia lining the perivisceral cavity.

Respiration is effected by the general surface of the body, or by distinct external gills or branchiæ.

The excretory organs of the Annelides are the so-called "segmental organs." In their simplest form (as in the ordinary Leeches), each segmental organ is in the form of a much-folded tube, partly labyrinthic, partly vesicular, often with an appended cæcum, and opening externally by a distinct aperture or "stigma," but having no internal communication with the body-cavity. In these cases, the segmental organs may be regarded as representing the kidneys of the higher animals.

In the higher *Annelida*, the segmental organs are usually in part subordinated to the function of reproduction. In these cases (fig. 127) the inner surface of the convoluted tube, which constitutes the segmental organ, is ciliated; and the tube not only opens exteriorly by a distinct "stigma," but also communicates internally with the perivisceral cavity by a widely patulous, trumpet-shaped, internally-ciliated infundibulum (fig. 127, *i*), by which the products of generation are taken up and conveyed to the outer medium. Very usually, also, there are appended to the tube of the segmental organ blind glandular pouches, which represent the kidneys, or in other cases cæcal appendices (fig. 127, *s*) for storing up the generative products.

The nervous system consists of a double, ventral, gangliated cord, which is traversed anteriorly by the œsophagus; the "præ-œsophageal," or "cerebral," ganglia being connected by lateral cords or commissures with the "post-œsophageal" ganglia. Pigment-spots, or "ocelli," sometimes of high organisation, are present in many, generally upon the proboscis, sometimes in each segment, or on the branchiæ, or on the tail; and the head often supports two or more feelers, which differ from the "antennæ" of Insects and Crustacea in not being jointed.

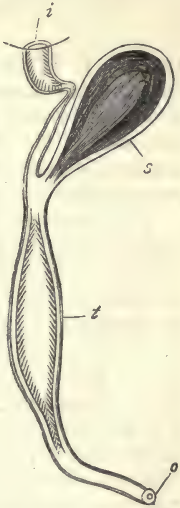

Fig. 127.—Segmental organ of of a Chætopodous Annelide (*Alciopa*), enlarged. *o* External aperture or stigma; *t* Tubular and ciliated portion of the segmental organ; *s* Seminal receptacle; *i* Ciliated infundibulum opening into the body-cavity. (After Claparède.)

The sexes in the *Annelida* are sometimes distinct, and sometimes united in the same individual. The embryos are almost universally ciliated, and even in the adult cilia are almost always, if not always, present—in both of which respects this class differs from the *Arthropoda*.

The *Annelida* may be divided into two sections, characterised by the presence or absence of external respiratory organs or branchiæ. The Abranchiate section comprises the Leeches and the Earth-worms; whilst the Branchiate division includes the Tube-worms (*Tubicola*) and the Sand-worms (*Errantia*). The *Annelida* are also often divided into two sections, called *Chætophora* and *Discophora*, according as locomotion is effected by chitinous setæ (Earth-worms, Tube-worms, and Sand-worms) or by suctorial discs (Leeches).

CHAPTER XXVIII.

ORDERS OF ANNELIDA.

ORDER I. HIRUDINEA (*Discophora* or *Suctoria*).—This order includes the Leeches, and is characterised by *the possession of a locomotive and adhesive sucker, posteriorly or at both extremities, and by the absence of bristles and foot-tubercles. The sexes are mostly united in the same individual, and the young do not pass through any metamorphosis.*

The Leeches are vermiform, mostly aquatic animals, chiefly inhabiting fresh water, though a few species are marine. Locomotion is effected either by swimming by means of a serpentine bending of the body, or by means of one or two suctorial discs. In those forms in which there is only a single sucker (posterior), the head or anterior extremity of the body can be converted into a suctorial disc. The body is ringed, as many as one hundred annulations being present in the common Leech; but it is not divided into distinct somites, and, with rare exceptions (*Branchellion*), there are no lateral appendages of any kind. The mouth is placed at the front end of the body, and may or may not be furnished with teeth. The pharynx is muscular; the gullet leads into a stomach with, usually, capacious lateral cæca (fig. 128, B); and the anus is placed in front of or at the bottom of the posterior sucker. The alimentary canal is united with the integument by a spongy tissue, formed of vascular sinuses, which more or less completely obliterate the body-cavity, and in which the blood circulates. The pseudohæmal system generally consists, in addition to the sinuses just alluded to, of four principal longitudinal trunks, devoid of special dilatations. Respiration is carried on mainly by the soft integument, possibly assisted by the "segmental organs," and, in the case of *Branchellion*, by the vascular leaf-like appendages on the sides of the body. The "segmental organs" are in the form of a larger or smaller number of sacs (fig. 128, B), which open upon the abdominal surface by so many pores or "stigmata." The function of these sacculi appears to be excretory, and in the majority of the *Hirudinea* they are closed internally, and only open externally by the "stigmata." In some of the *Hirudinea*, however, the "segmental organs" agree with those of the great majority of the Annelides in not only opening externally, but in also communicating internally with the perivisceral cavity.

The segmental organs of the Leeches differ further from those of the other *Annelida* in not being in any way connected with the process of reproduction.

The nervous system consists of a præ-œsophageal ganglion, which gives branches to a number of simple eyes, or ocelli, which are placed on the head, and which is united by lateral œsophageal cords to the ventral gangliated chain. The ventral chain of the common Leech carries twenty-three successive pairs of ganglia, marking the composition of the body out of the same number of segments or "zonites."

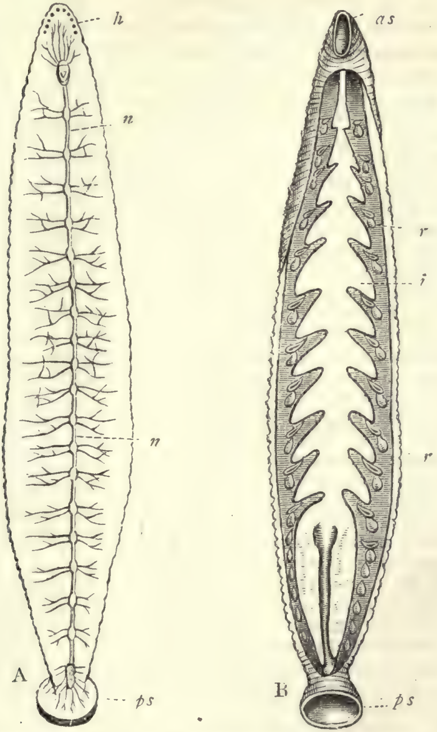

Fig. 128.—A, Diagram of the Leech, showing the nervous system, and the ten eyes placed on the top of the head. B, The leech dissected to show the alimentary canal (*i*), and the "segmental organs," or so-called "respiratory sacs" (*r r*); *as* Anterior sucker; *ps* Hinder sucker; *n n* Nervous system; *h* Head, carrying the eye-spots.

The sexes are almost always united in the same individual, but the Leeches are nevertheless incapable of self-fertilisation. Reproduction, also, is always effected by means of the sexes, and never by fission or gemmation. The generative products, instead of being discharged into the perivisceral cavity (as in the *Annelida* generally), reach the surface by special apertures. The ova are deposited in delicate chitinous capsules or "cocoons;" and the young, on being hatched, undergo no metamorphosis, but are essentially similar to the adult in all except their size.

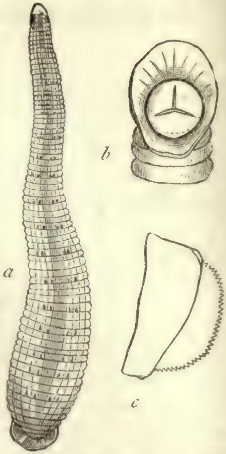

Fig. 129.—Hirudinea. *a* The Medicinal Leech (*Sanguisuga officinalis*), natural size; *b* Anterior extremity of the same magnified, showing the sucker and triradiate jaws; *c* One of the jaws detached, showing the semicircular toothed margin.

The common Horse-leech, *Hæmopsis*, is only provided with blunt teeth; but the Medicinal Leech (*Sanguisuga medicinalis*, fig. 129) has its mouth furnished with three crescentic jaws, the convex surfaces of which are serrated with minute teeth. This species is chiefly imported from Germany, Bohemia, and Russia. In *Sanguisuga officinalis*, the Hungarian Leech, also used in medicine, the abdomen has numerous black spots. In both species the oral and caudal extremities are narrowed before dilating into the suckers, and the body has from ninety to one hundred rings. The anterior sucker is small, with a lancet-shaped upper lip, carrying ten ocelli on its superior surface. The posterior sucker is round, obliquely placed, and separated from the body by a distinct constriction. The alimentary canal, usually termed the "stomach" in its anterior portion, occupies the greater part of the body-cavity, and is furnished with eleven membranous pouches or diverticula on each side. There are seventeen segmental organs on each side, opening by minute stigmata on the lower surface of the body. The opening of the male reproductive organs is in the anterior third of the body, between the twenty-seventh and twenty-eighth rings; that of the female organs, in the form of a small fissure, five rings behind. Impregnation of the hermaphrodite individuals is mutual, and the ova are deposited in moist earth, within a cocoon, where they remain until hatched. The marine *Pontobdellæ* have the body tuberculated, and attach themselves to the bodies of fishes, especially skates. The anterior sucker is separated in these from the body by a distinct constriction or neck. In the little freshwater *Clepsines* the anterior sucker is wanting, and there is a proboscidiform mouth. They are found attached to the stems of water-plants, or to aquatic animals of different kinds. *Branchiobdella* lives upon the gills of Crustaceans; and *Branchellion* infests the gills of various Fishes, such as the Turbot. A few Leeches inhabit damp situations on land.

ORDER II. OLIGOCHÆTA (*Terricola*).—The members of this order, comprising the Earth-worms (*Lumbricidæ*) and the Water-worms (*Naïdidæ*), are distinguished by the fact that *their locomotive appendages are in the form of chitinous setæ or* *bristles attached in rows to the sides and ventral surface of the body. No branchiæ are present. They are all hermaphrodite; and the young pass through no metamorphosis.* The *Oligochæta* are divided into the two groups of the *Terricolæ* or Earth-worms, and the *Limicolæ* or Mud-worms and Water-worms (*Sænuridæ* and *Naïdidæ*).

In the common Earth-worm (*Lumbricus*) the body is cylindrical, attenuated at both extremities, and carrying in the adult a thickened zone, which occupies from six to nine rings in the anterior part of the body, is connected with reproduction, and is termed the "clitellum," or "saddle." Locomotion is effected by eight rows of short bristles or setæ, four of which are placed laterally and four on the ventral surface of the body; these representing the foot-tubercles of the higher Annelides. The mouth is edentulous, and opens by a muscular pharynx into a short œsophagus, which leads to a muscular crop, or "pro-ventriculus," succeeded by a second muscular dilatation, or gizzard. Salivary glands open into the pharynx, and other glands, probably digestive, open into the gullet. The intestine is continued straight to the anus, and is constricted in its course by numerous transverse septa, springing from the walls of the perivisceral cavity. The perivisceral cavity (as in all the *Oligochæta*) is lined by a cellular membrane, which is continuous with a yellow cellular layer covering the intestine and large vessels, and which casts off its cells into the perivisceral fluid. The pseudohæmal system consists of three principal longitudinal trunks and their branches, filled with a red non-corpusculated fluid; and there exists, in even greater numbers, the same series of lateral sacculi or "segmental organs" which we have seen in the Leeches, and which have either a respiratory or a renal function. In all the *Oligochæta* the segmental organs communicate internally with the perivisceral cavity as well as externally with the outer medium. A portion of the segmental organs is ciliated, and in all cases the segmental organs of certain of the segments have the special function of acting as efferent ducts for the generative organs. The body-cavity is filled with a colourless corpusculated "blood." The reproductive organs consist of two pairs of testes, opening on the fifteenth segment, and one pair of ovaries, of which the oviducts open on the fourteenth segment. In addition, the animal also possesses a pair of seminal reservoirs in the tenth and eleventh rings, and five pairs of glands for secreting the capsules of the eggs. The ova are deposited in chitinous capsules, and the young pass through no metamorphosis.

Of the little *Naïdidæ*, the most familiar is the *Tubifex rivulorum*, which is of common occurrence in the mud of ponds and streams. It is from half an inch to one inch and a half in length, and of a bright-red colour. The pseudohæmal system is provided with two contractile cavities or hearts; and there is present the same system of lateral tubes, opening externally by pores, as occurs in the Earth-worms.

The *Naïdidæ* are chiefly noticeable on account of the singular process of non-sexual reproduction which they present before they attain sexual maturity. In this process the *Naïs* throws out a bud between two rings, at a point generally near the middle of the body. Not only is this bud developed into a fresh individual, but the two portions of the parent marked out by the budding point likewise become developed into separate individuals. The portion of the parent in front of the bud develops a tail, whilst the portion behind the bud develops a head. Prior to the detachment of the bud, other secondary buds are formed from the same segment, each in front of the one already produced; and in this way, before separation takes place, a chain of organically connected individuals is produced, all of which are nourished by the anterior portion of the primitive worm. Besides their non-sexual reproduction, the *Naïdidæ* possess generative organs when adult, and exhibit true sexual reproduction. With the development of the generative organs, a new segment is added to the body, and certain other modifications take place; so that the process of attaining sexual maturity is actually attended with a species of metamorphosis.

As regards their distribution in space, the *Oligochæta* have a cosmopolitan range. The most are either terrestrial, or inhabit fresh waters, burrowing in mud or sand; but a few are marine.

ORDER III. TUBICOLA (*Cephalobranchiata*).—*Animal protected by a tube; locomotive organs in the form of foot-tubercles, carrying setæ; breathing-organs in the form of branchiæ carried on or near the head. Sexes almost always distinct. A metamorphosis in development.* The Annelides which are included in this order inhabit tubes, which may be calcareous, and secreted by the animal itself, or may be composed of grains of sand or pieces of broken shell, cemented together by a glutinous secretion from the body. The body-rings are mostly provided with fasciculi of bristles set upon lateral foot-tubercles or parapodia, by means of which the animal is enabled to draw itself in and out of its tube.

The *Tubicola* are often united with the order of the *Errantia* under the name of *Polychæta;* and though collectively spoken of as "Branchiate Annelides," they do not always possess specialised respiratory organs.

The protecting tube of the Tubicolous Annelides may be composed of carbonate of lime (*Serpula*), of grains of sand (*Sabellaria*), or of sand, pieces of shell, and other adventitious particles cemented together by a glutinous secretion from the body (*Terebella*); or it may be simply membranaceous or leathery (*Sabella*). Sometimes the tube is free and non-adherent (*Pectinaria*); more commonly it is attached to some submarine object by its apex or by one side (*Serpula* and *Spirorbis*). Sometimes the tube is single (*Spirorbis*); sometimes the animal is social, and the tubes are clustered together in larger or smaller masses (*Sabellaria*).

When the tube is calcareous, it presents certain resemblances to the shells of some of the Molluscs, such as *Vermetus* and *Dentalium*. In the living state it is easy to make a distinction between these, for the Tubicolar Annelides are in no way organically attached to their tubes, whereas the Molluscs are always attached to their shell by proper muscles.

The pseudohæmal system has its usual arrangement, and the contained fluid is usually red in colour, but is olive-green in *Sabella*. The respiratory organs are in the form of filamentous branchiæ, attached to, or near, the head, generally in two lateral tufts, arranged in a funnel-shaped or spiral form. Each filament is fringed with vibrating cilia, and the tufts are richly supplied with fluid from the pseudohæmal system. There is no special apparatus required to drive the blood back to the heart, but this is effected by the contractile power of the gills themselves. From the position of the branchiæ upon, or near, the head, the *Tubicola* are often known as the "cephalobranchiate" Annelides (fig. 130).

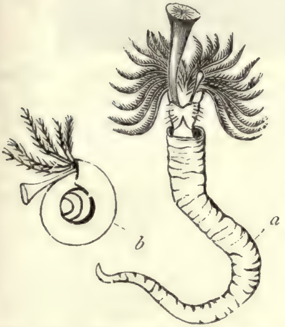

Fig. 130. — Tubicola. *a Serpula contortuplicata*, showing the branchiæ and operculum; *b Spirorbis communis.*

Reproduction in the *Tubicola* is generally sexual, the sexes being almost invariably in different individuals; but fission has also been noticed to occur. As regards their development, the young pass through a distinct metamorphosis. The larvæ (fig. 131, A and D) are freely locomotive, furnished with eye-spots, and swimming actively by means of cilia, which are principally aggregated into two rings or circlets, one placed on the head, the other at the hinder end of the body. The tentacles are developed at an early period, and the larva undergoes segmentation. Finally, the cilia disappear, the larva becomes stationary, and the protective tube of the adult is secreted. The young Tubicolar Annelide thus resembles the permanent condition of the Errant forms; and the stationary condition of the adult, accompanied by the loss of its sense-organs, may be regarded as an instance of "retrograde development."

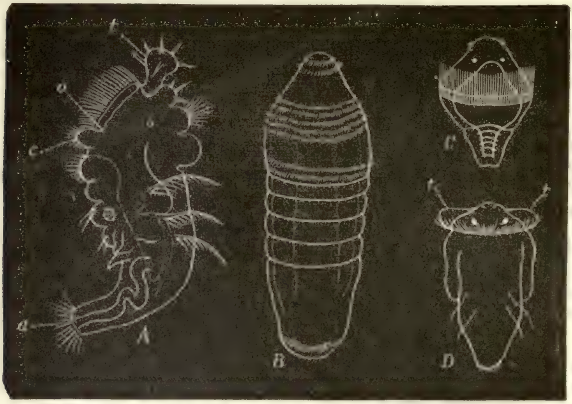

Fig. 131.—Development of Tubicolar and Errant Annelides. A, Larva of *Terebella*; *o* Position of the mouth; *a* Anus, surrounded by the posterior circlet of cilia; *c* Anterior circlet of cilia; *t* Tentacle. B, Polytrochal larva of *Arenicola*; C, Larva of *Phyllodoce*. D, Larva of *Spirorbis*; *t t* Tentacles. All the figures are greatly magnified. (After Claparède, Schultze, and A. Agassiz.)

The most familiar of the Tubicola is the *Serpula* (fig. 130, *a*), the contorted and winding calcareous tubes of which must be known to almost every one as occurring on shells or stones on the sea-shore. One of the cephalic cirrhi in *Serpula* is much developed, and carries at its extremity a conical plug, or operculum, whereby the mouth of the tube is closed when the animal is retracted within it. The operculum of *Serpula* has a more than ordinary interest in the fact that it is the only instance in the *Annelida* in which calcareous matter is deposited within the integument. In *Spirorbis* (fig. 130, *b*) the shelly tube is coiled into a flat spiral, one side of which is fixed to some solid object. It is of extremely common occurrence on the fronds of sea-weed and on other submarine objects.

Equally familiar with *Serpula* is *Terebella*, the animal of which is included in a tube composed of sand and fragments of shell, cemented together by a glutinous secretion. In the *Sabellidæ* the tube is composed of granules of sand or mud. In *Pectinaria* the tube is free, membranous, or papyraceous, covered with sand-grains, and in the form of a reversed cone of considerable length. In *Phoronis*, the tube is membranous, and the branchiæ are carried upon a horse-shoe-shaped process, which is strikingly similar to the "lophophore" of the *Polyzoa*.

ORDER IV. ERRANTIA (*Chætopoda*, or *Nereidea*).—This order comprises *free* Annelides,* *which possess setigerous foot-tubercles. The respiratory organs are generally in the form of tufts of external branchiæ, arranged along the back or the sides of the body. The sexes are distinct, and the young pass through a metamorphosis.* This order includes most of the animals which are commonly known as Sand-worms and Sea-worms, together with the familiar Sea-mice.

The integument is soft, and the body is distinctly divided into a number of rings or segments, each of which, in the typical forms, possesses the following structure. The segment consists of two arches, a lower or "ventral arc," and an upper or "dorsal arc," with a "foot-tubercle" on each side. Each foot-tubercle consists of an upper process, or "notopodium," and a lower process, or "neuropodium," each of which carries a tuft of bristles, or "setæ," (rarely, a single bristle) and a species of tentacle termed the "cirrhus" (fig. 126).

The outer, cuticular layer of the body is generally more or less chitinous, and is often iridescent. Below this is a muscular layer, by which the movements of the animal are effected, and which encloses the "perivisceral cavity." This cavity runs the whole length of the body, and is lined by a special, often ciliated membrane, which is reflected upon the alimentary canal and other internal organs. It is usually more or less subdivided by imperfect partitions, and is filled with an albuminous fluid containing floating corpuscles, and corresponding with the blood. This so-called "chylaqueous fluid," "performs one of the functions of an internal skeleton, acting as the fulcrum or base of resistance to the cutaneous muscles, the power of voluntary motion being lost when the fluid is let out" (Owen).

The anterior extremity of the body is usually so modified as to be distinctly recognisable as the head, and is provided with eyes, and with two or more feelers, which are not jointed, and are therefore not comparable with the antennæ of Crustacea and Insects. The mouth is placed on the inferior surface of the head, and is often furnished with one or more pairs of horny jaws, working laterally. The pharynx is muscular, and forms a sort of proboscis, being provided with special muscles, by means of which it can be everted and again retracted. In most there is no distinction between stomach and intestine, and the epithelium of the alimentary canal, like that of the preceding orders, is ciliated.

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* Fritz Müller describes an errant Annelide belonging to the *Amphinomidæ* as living parasitically within the shell of the common Barnacle (*Lepas*), showing that the members of this group may sometimes lose their free habit.

The pseudohæmal system is well developed, and consists essentially of a long dorsal vessel, and a similar ventral one, connected by transverse branches, and sometimes furnished at the bases of the branchiæ with pulsating dilatations. The contained fluid is mostly red, but is yellow in *Aphrodite* and *Polynoe*, and in no case contains corpuscles.

Respiration is carried on by means of a series of external branchiæ or gills, arranged in tufts upon the sides of the body on its dorsal aspect, along the middle of the body only, or along its entire length; but in some forms the gills may be rudimentary or wanting. From the position of the branchiæ, the members of this order are often spoken of as the "Dorsibranchiate" (or more properly "Notobranchiate") Annelides.

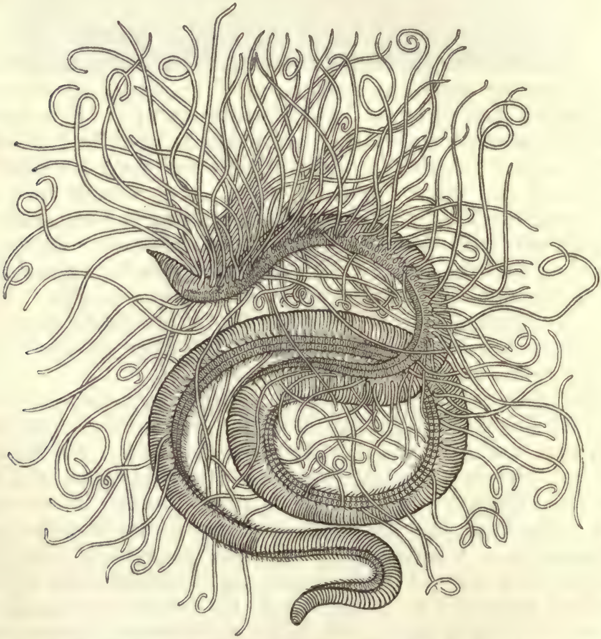

Fig. 132.—*Cirrhatulus grandis*, an "Errant Annelide," in its living condition. (After Verrill.)

The "segmental organs," with few exceptions, communicate with the perivisceral cavity internally, and in certain segments they are always specialised to act as efferent ducts for the reproductive organs.

The nervous system in the *Errantia* has its typical form, consisting of a double gangliated ventral cord, two ganglia of which are appropriated to each segment. The præ-œsophageal, or cerebral, ganglia are of large size, and send filaments to the ocelli and feelers.

The sexes in the *Errantia* are in different individuals, and reproduction is usually sexual, though in some cases gemmation is known to occur. The process of gemmation is carried on by a single segment, and so long as it continues, the budding individual remains sexually immature, though the young thus produced develop generative organs. Thus, there is in these cases a kind of alternation of generations, or rather an alternation of generation and gemmation; the oviparous individuals producing eggs from which the gemmiparous individuals are born; these, in their turn, but by a non-sexual process, producing the oviparous individuals. While the form of gemmation just alluded to has long been known as not uncommonly taking place among the Errant Annelides, no example of *continuous* gemmation has until lately been recognised in any Annelide. Recently, however, Dr M'Intosh has described a remarkable species of *Syllis* (*S. ramosa*), which inhabits a Hexactinellid Sponge from the Philippines, and in which the thread-like body is intricately branched, giving off lateral offsets, and thus becoming a truly composite organism. This singular form is further remarkable in the fact that no traces of a *head* have hitherto been discovered, so that it is probable that the entire branched organism possessed but a single head.

Not only does gemmation occur among the Errant Annelides, but, in a few instances, fission has been noticed to take place. Occasionally, also, the males and females differ from one another, and both may differ from the sexless forms, when these exist. Thus, *Heteronereis* is founded upon the sexless forms of *Nereis;* whilst the species of the genus *Autolytus*, amongst the *Syllidea*, exhibit a still more remarkable polymorphism, the males and females being extremely dissimilar, and there being in addition a third sexless form, which produces the sexual individuals by gemmation at its hinder extremity.

The embryo usually appears, on its liberation from the ovum, as a free-swimming, ciliated body, possessing a mouth, intestine, and anus. The cilia are primarily diffused, but become aggregated so as to form a single median belt, or two bands, one about each extremity, or a series of bands (fig. 131, B and C). The head, with its feelers and eye-specks, appears at one extremity, whilst the segments of the body begin to be formed at the other. Each segment is developed in four parts, the two principal ones forming half-rings, united by shorter side-pieces, from which the setigerous foot-tubercles are developed. The ciliated band or bands finally disappear, and new rings are rapidly added by intercalation between the head and the segments already formed.

Amongst the best known of the *Errantia* is the common Lob-worm (*Arenicola piscatorum*, fig. 133, C), which is used by fishermen for bait. The Lob-worm lives in deep canals, which it hollows out in the sand of the sea-shore, literally eating its way as it proceeds, and passing the sand through the alimentary canal, so as to extract from it any nutriment which it may contain. It possesses a large head, without eyes or jaws, and with a short proboscis. There are thirteen pairs of branchiæ placed on each side in the middle of the body.

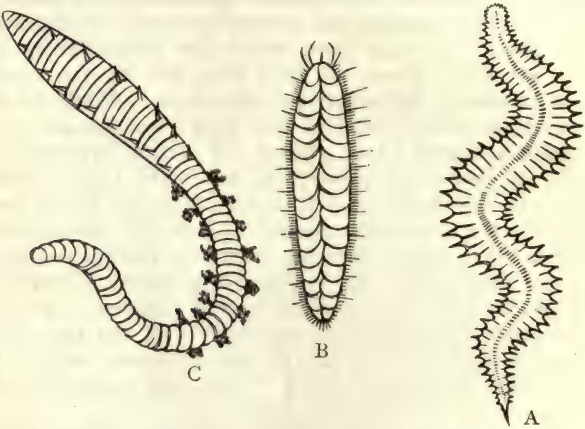

Fig. 133.—Errant Annelides. A, Hairy-bait (*Nephthys*); B, Sea-mouse (*Aphrodite*); C, Lob-worm (*Arenicola*). (After Gosse.)

In the Sea-mouse (*Aphrodite*, fig. 133, B), the back is covered with a double row of membranous imbricated plates, which are called "elytra," or "squamæ," and respiration is effected by the periodical elevation and depression of these plates, whereby water is alternately admitted into, and expelled from, a space beneath them. This space is separated by a membrane from the perivisceral cavity below, and contains the gills in the form of small fleshy crests. The pharynx is thick and muscular, and can be everted like a proboscis, and the intestine has a number of lateral branched cæca.

In the *Nereidæ*, or "Sea-centipedes," the body is greatly elongated, and consists of a great number of similar segments, with rudimentary branchiæ.

The head is distinct, and carries eyes and feelers, whilst the mouth is furnished with a large proboscis, and often with two horny jaws. In the *Eunicea* the branchiæ are usually well developed and of large size, and the mouth is armed with seven, eight, or nine horny jaws. *Eunice gigantea* attains sometimes a length of over four feet, and may consist of more than four hundred rings.

All the Errant Annelides are marine, occurring in all seas from the Arctic Ocean to the equator, and extending to great depths. A few forms (*e. g.*, *Tomopteris*) are pelagic. Others live in sand and mud; whilst others hide under stones, or in fissures in rock-pools; and others, again, bore holes in calcareous rocks. A few live as "commensals" on other animals.

DISTRIBUTION OF ANNELIDA IN TIME.—Of the *Annelida* the only orders which are known to have left any traces of their existence in past time are the *Tubicola* and the *Errantia*; of which the former are known by their investing tubes, whilst the latter are recognised by the tracks which they left upon ancient sea-bottoms, or by their burrows in sand or mud, or, more satisfactorily, by their horny jaws, remains of this latter nature being known from deposits as old as the Lower Silurian.

Tubicolar Annelides are known to occur from the Silurian rocks upwards. The well-known Silurian fossil *Tentaculites*, has been often referred to the *Tubicola*, but is almost certainly Pteropodous. *Cornulites*, *Serpulites*, *Ortonia*, *Trachyderma*, *Spirorbis*, and *Conchicolites* are, however, genuine Silurian *Tubicola*. The *Microconchus carbonarius* is a little spiral Tubicolar Annelide, nearly allied to the *Spirorbis* (fig. 130, *b*) of our seas, which is not uncommonly found in strata belonging to the Carboniferous period; and the genus *Spirorbis* itself is represented even in the Silurian period.

CLASS III. CHÆTOGNATHA (Huxley).—*Elongated cylindrical animals having the hinder extremity of the body furnished with an integumentary fin. Anterior end of the body provided with setæ and corneous jaws. No foot-tubercles. Sexes united in the same individual.*

This class includes only the singular pelagic animals belonging to the genus *Sagitta*, the precise systematic position of which is somewhat doubtful. They appear, however, to form a connecting link between the Annelides on the one hand, and the free Nematoids on the other hand.

The *Sagittæ* (fig. 134) have elongated transparent bodies, rarely over an inch in length, having the hinder end of the body expanded into a striated caudal fin, similar fins often existing on the sides of the body as well. The head carries a series of setæ placed in front of the mouth, and the oral aperture is furnished with unciform corneous bristles or "falces," which act as jaws. The alimentary canal is straight, and terminates in an anus placed at the base of the tail below.

"A single oval ganglion lies in the abdomen, and sends, forwards and backwards, two pairs of lateral cords. The lateral cords unite in front of and above the mouth into a hexagonal ganglion. This gives off two branches which dilate at their extremities into the spheroidal ganglia, on which the darkly pigmented imperfect eyes rest. The ovaries, saccular organs, lie on each side of the intestine and open on either side of the vent; *receptacula seminis* are present. Behind the anus, the cavity of the tapering caudal part of the body is partitioned into two compartments; on the lateral parietes of these, cellular masses are developed which become detached, and, floating freely in the compartment, develop into spermatozoa. These escape by spout-like lateral ducts, the dilated bases of which perform the part of *vesiculæ seminales.* The embryos are not ciliated, and undergo no metamorphosis" (Huxley).

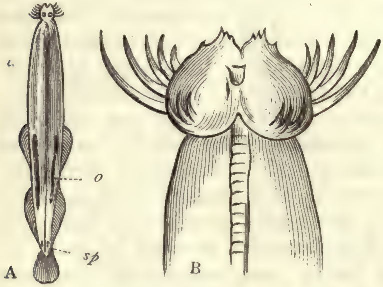

Fig. 134.—Morphology of *Chætognatha.* A, *Sagitta tricuspidata*, of the natural size: *o* One of the ovaries; *sp* Orifice of one of male organs of reproduction. B, Head of the same, viewed from beneath and greatly enlarged, showing the horny, setiform jaws. (After Saville Kent.)

The species of *Sagitta* are found, living in the open sea, in the Mediterranean, and in the Atlantic and Pacific Oceans.

LITERATURE.

GEPHYREA.

1. "History of British Starfishes and other Animals of the Class Echinodermata." Edward Forbes. 1841.
2. "Mémoire sur l'Echiure." Quatrefages. 'Annales Sci. Nat.' 1847.
3. "Ueber Thalassema." Krohn. 'Arch. für Anat. und Physiologie.' 1842.
4. "Observationes anatomicæ de vermibus quibusdam maritimis." Müller. 1852.
5. "Larven von Phascolosoma." Selenka. 'Zeitschrift Wiss. Zool.' 1875.
6. "Beiträge zur anatomischen und systematischen Kenntniss der Sipunculiden." Keferstein. 'Zeitschr. für Wiss. Zool.' 1865.

ANNELIDA.

7. "Monographie de la Famille des Hirudinés." Moquin-Tandon. 1846.
8. "De lumbrici terrestris historia naturali, nec non anatomia." Morren. 1829.
9. "Observations on the Organisation of Oligochætous Annelides." Ray Lankester. 'Annals of Nat. Hist.' 1871.
10. "Structure of Tubifex." W. C. M'Intosh. 'Trans. Roy. Soc. Edin.' 1870-71.
11. Article "Annelides," in Todd's 'Encyclopædia of Anatomy and Physiology.' Milne-Edwards. 1835.
12. Article "Annelida," in 'Encyclopædia Britannica,' 9th ed. vol. ii. W. C. M'Intosh. 1875.
13. "Système des Annélides." Savigny. 1820.
14. "Classification des Annélides," &c. Audouin and Milne-Edwards. 'Annales Sci. Nat.' 1832-33.
15. "Études sur les types inférieures de l'embranchement des Annélés." Quatrefages. 'Annales Sci. Nat.' 1848-54.
16. "Histoire Naturelle des Annélés." Quatrefages. 1865.
17. "Zur Anatomie und Physiologie der Kiemenwürmer." Grube. 1838.
18. "Die Familien der Anneliden." Grube. 'Archiv für Naturgeschichte.' 1850.
19. "Recherches anatomiques sur les Annélides." Claparède. 1861.
20. "Recherches anatomiques sur les Oligochétes." Claparède. 1862.
21. "Structure des Annélides sédentaires." Claparède. 1873.
22. "Die Borstenwürmer." Ehlers. 1864 and 1868.
23. "Nordiske Hafs Annulater." Malmgren. 1866.
24. "Annulata polychæta Spitzbergiæ," &c. Malmgren. 1867.
25. "Catalogue of the British Non-parasitical Worms in the collection of the British Museum." Johnston. 1865-67.
26. "Les Annélides Chétopodes du Golfe de Naples." Claparède. 1868. Supplement, 1870.
27. "On the Young Stages of a few Annelides." Alexander Agassiz. 'Ann. Lyceum Nat. Hist.' New York. 1866.
28. "Christiania-Fjords Fauna. Anneliden." O. Sars. 1873.
29. "Life-Histories of Animals." Packard. 1876.
30. "Grönland's Annulata dorsibranchiata." Oersted. 'Danske Selsk. Skriften.' 1843.

CHÆTOGNATHA.

31. "Species of Sagitta." Busk. 'Quart. Journ. Microscop. Science.' 1856.
32. "Ueber die Entwickelung der Sagitta." Gegenbaur. 1857.
33. "On a New Species of Sagitta from the South Pacific." Saville Kent. 'Annals Nat. Hist.' 1870.

CHAPTER XXIX.

ARTHROPODA.

DIVISION II. ARTHROPODA, OR ARTICULATA.—The remaining members of the sub-kingdom *Annulosa* are distinguished by the possession of *jointed appendages, articulated to the body;* and they form the second primary division—often called by the name *Articulata.* As this name, however, has been employed in a wider sense than is understood by it here, it is perhaps best to adopt the more modern term *Arthropoda.*

The members of this division, comprising the *Crustacea* (Lobsters, Crabs, &c.), the *Arachnida* (Spiders and Scorpions), the *Myriapoda* (Centipedes), and the *Insecta*, are distinguished as follows:—

The body (fig. 112) is composed of a series of segments, arranged along a longitudinal axis; each segment or "somite," occasionally, and some almost always, being provided with articulated appendages. Both the segmented body and the articulated limbs are more or less completely protected by a chitinous exoskeleton, formed by a hardening of the cuticle. The appendages are hollow, and the muscles are prolonged into their interior. The nervous system in all, at any rate in the embryonic condition, consists of a double chain of ganglia, placed along the ventral surface of the body, united by longitudinal commissures, and traversed anteriorly by the œsophagus. The hæmal system, when differentiated, is placed dorsally, and consists of a contractile cavity, or heart, provided with valvular apertures, and communicating with a perivisceral cavity, containing corpusculated blood. Respiration is effected by the general surface of the body, by gills, by pulmonary sacs, or by tubular involutions of the integument, termed "tracheæ." In no member of the division are vibratile cilia known to be developed. According to Professor Huxley, an additional constant character of the *Arthropoda* is to be found in the structure of the head, which is typically composed of six segments, and never contains less than four.

The *Arthropoda* are divided into four great classes—viz., the *Crustacea*, the *Arachnida*, the *Myriapoda*, and the *Insecta;* which are roughly distinguished as follows:—

1. CRUSTACEA.—*Respiration by means of gills, or by the general surface of the body. Two pairs of antennæ. Locomotive appendages, more than eight in number, borne by the segments of the thorax and, usually, of the abdomen also.*

2. ARACHNIDA.—*Respiration by pulmonary vesicles, by tracheæ, or by the general surface of the body. Head and thorax united into a cephalothorax. Antennæ (as such) absent. Legs eight. Abdomen without articulated appendages.*

3. MYRIAPODA.—*Respiration by tracheæ. Head distinct; remainder of the body composed of nearly similar somites. One pair of antennæ. Legs numerous.*

4. INSECTA.—*Respiration by tracheæ. Head, thorax, and abdomen distinct. One pair of antennæ. Three pairs of legs borne on the thorax. Abdomen destitute of limbs. Generally two pairs of wings on the thorax.*

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CHAPTER XXX.

CRUSTACEA.

CLASS I. CRUSTACEA.—The members of this class are commonly known as Crabs, Lobsters, Shrimps, King-crabs, Barnacles, Acorn-shells, &c. They are nearly allied to the succeeding order of the *Arachnida* (Spiders and Scorpions); but may usually be distinguished by the possession of articulated appendages upon the abdominal segments, by the possession of two pairs of antennæ, and by the presence of branchiæ.

The body is composed of a number of definite rings or segments ("somites"), each of which may be provided with a pair of jointed appendages. With rare exceptions, some of the somites of the adult always carry appendages; and one or more pairs are almost invariably adapted for mastication. The nervous system of the embryo has the typical Annulose form of a chain of ventral ganglia, between the first two pairs of which the gullet passes. No water-vascular system is present; but there is generally a true blood-vascular system. The heart, when present, is placed on the opposite side of the alimentary canal to the ventral nerve-chain, and communicates by valvular apertures with a surrounding venous sinus—the so-called "pericardium." When differentiated breathing-organs are present, these are always in the form of branchiæ or gills, adapted for respiring air dissolved in water.

In addition to these characters, the body in the *Crustacea* is always protected by a chitinous or sub-calcareous exoskeleton, or "crust," and the number of pairs of articulated limbs is generally from five to seven. They all pass through a series of metamorphoses before attaining their adult condition, and every part that is found in an embryonic form, even though only temporarily developed, may be represented in a permanent condition in some member of a lower order.

As regards the classification of the Crustacea, the tabular view which follows embodies the arrangement which is most generally adopted, and the diagnostic characters of each order will be briefly given, a more detailed description being reserved for the more important divisions of the class. Before proceeding further, however, it will be as well to give a description of the morphology of a typical *Crustacean*, selecting the lobster as being as good an example as any.

The body of a typical *Crustacean* may be divided into three regions—a *head*, a *thorax*, and an *abdomen*, each of which is composed of a certain number of somites, though opinions differ both as to the number of segments in each region, and as to their number collectively. By the majority of authorities the body is looked upon as being typically composed of *twenty-one* segments, of which seven belong to the head, seven to the thorax, and seven to the abdomen. In many *Crustacea*, however, the segments of the head and thorax are welded together into a single mass, called the "cephalothorax;" in which case the body shows only two distinct divisions, of which the cephalothorax claims fourteen segments, whilst the remaining seven are allotted to the abdomen. By Professor Huxley, on the other hand, the terminal joint of the abdomen, termed the "telson," is regarded as an *appendage*, and not as a somite. Upon this view, the body of a typical Crustacean will consist of *twenty* segments only. Professor Huxley, further, differs from the above-mentioned view in the allotment of the somites, and he divides the body into six cephalic, eight thoracic, and six abdominal somites.* Fritz Müller and Claus deny that the eyes are limbs, or that there is an ocular segment. The telson, on the other hand, is regarded by the former as a true somite, chiefly because the intestine usually opens in this piece.

Whilst the normal number of segments in the body of any Crustacean may thus be regarded as being twenty-one, or twenty, there occur cases in which this number is exceeded, and others in which the number of somites is apparently less. In these latter cases, however, the apparent diminution in the

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* In reality the five hindmost segments of the eight somites here allotted to the thorax, should alone be regarded as constituting the *abdomen* proper, —that is, the region corresponding to the "abdomen" of insects and Arachnida. The six somites allotted above to the *abdomen* belong to what is strictly called the "*post-abdomen*" of the *Crustacea.*

number of segments is really due to some having been fused together, as is shown by the number of appendages, since each pair of appendages indicates a separate somite. In other cases, however, in which the number of somites is really less than the normal, this is due to an arrest of development. According to Milne-Edwards:—

"In the embryo these segments are formed in succession from before backwards, so that, when their evolution is checked, the latter, rather than the earlier, rings are those which are wanting; and, in fact, it is generally easy to see in those specimens of full-grown Crustaceous animals, whose bodies present fewer than twenty-one segments, that the anomaly depends on the absence of a certain number of the most posterior rings of the body." According to Dana, however, the abortion of segments with their appendages almost always takes place at the posterior end of the cephalothorax.

In no single example can a general view be obtained of the different segments and their appendages in the *Crustacea*. "Indeed the only segment that may be said to be persistent is that which supports the mandibles, for the eyes may be wanting, and the antennæ, though less liable to changes than the remaining appendages, are nevertheless subject to very extraordinary modifications, and have to perform functions equally various. Being essentially and typically organs of touch, hearing, and perhaps of smell, in the highest Decapods, they become converted into burrowing organs in the *Scyllaridæ*, organs of prehension in the *Merostomata*, claspers for the male in the *Cyclopoidea*, and organs of attachment in the *Cirripedia*. Not to multiply instances, we have presented to us in the *Crustacea* probably the best zoological illustration of a class, constructed on a common type, retaining its general characteristics, but capable of endless modification of its parts, so as to suit the extreme requirements of every separate species" (H. Woodward).

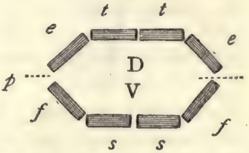

Fig. 135.—Theoretical figure illustrating the composition of the tegumentary skeleton of the Crustacea (after Milne-Edwards). D, Dorsal arc: *t t* Tergal pieces; *e e* Epimeral pieces. V, Ventral arc: *s s* Sternal pieces; *f f* Episternal pieces; *p p* Insertion of the extremities.

Taking the common Lobster (fig. 136) as a good and readily obtainable type of the *Crustacea*, the body is at once seen to be composed of two parts, familiarly called the "head" and the "tail," the latter being jointed and flexible. The so-called "head" is really composed of both the head, properly so called, and the thorax, which have coalesced so as to form a single mass, technically called the "cephalothorax." The so-called "tail," on the other hand, is truly the "abdomen." The various appendages of the animal are arranged along the lower surface of the body, and consist of the feelers, jaws, claws, legs, &c. The entire body, with the articulated

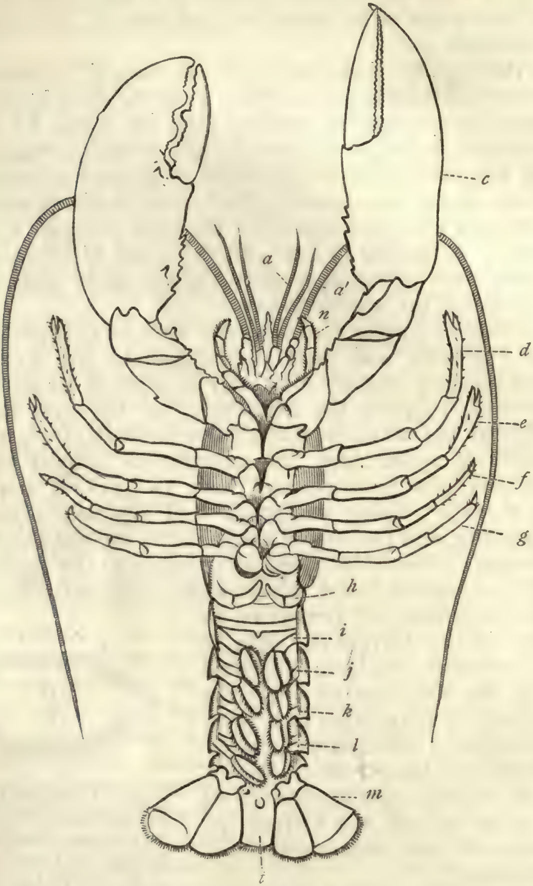

Fig. 136.—The common Lobster (*Homarus vulgaris*), viewed from below. *a* The lesser antennæ; *a'* The greater antennæ; *n* The last pair of foot-jaws; *c* The great claws, or first pair of legs; *d e f g* The last four pairs of walking legs; *h i j k l m* The six pairs of abdominal appendages, the last five being "swimmerets," and the last of all being greatly expanded; *t* The last segment of the body, without appendages.

appendages, is enclosed in a strong chitinous "shell," or exoskeleton, and the cephalothorax is covered by a great cephalic shield or plate, which is termed the "carapace."

Each segment of the body may be regarded as essentially composed of a convex upper plate, termed the "tergum," which is closed below by a flatter plate called the "sternum," the line where the two unite being produced downwards and outwards, into a plate, which is called the "pleuron" or "pleura" (fig. 137, 2).

Strictly speaking, the composition of the typical somite is considerably more complex, each of the primary arcs of the somite being really composed of four pieces. The tergal arc is composed of two central pieces, one on each side of the middle line of the body, united together and constituting the "tergum" proper. The superior arc is completed by two lateral pieces, one on each side of the tergum, which are termed the "epimera." In like manner the ventral or sternal arc is composed of a central plate, composed of two pieces united together in the middle line, and constituting the "sternum" proper; the arc being completed by two lateral pieces, termed the "episterna." These plates are usually more or less completely anchylosed together, and the true structure of the somite in these cases is often shown by what are called "apodemata." These are septa which proceed inwards from the internal surface of the somite, penetrating more or less deeply between the various organs enclosed by the ring, and always proceeding from the line of junction of the different pieces of the segment (fig. 135).

It must be borne in mind that though the so-called "head"—that is to say, the "cephalothorax"—of the Lobster is produced by an amalgamation of the various somites of the head and thorax, this is not the case with the great shield which covers this portion of the body. This shield—the so-called "cephalic buckler," or "carapace"—is not produced by the union of the tergal arcs of the various cephalic and thoracic segments, as would at first sight appear to be the case. On the contrary, the "carapace" in the higher *Crustacea* is produced by an enormous development of the tergal pieces, or of the "epimera" or one or two of the cephalic segments: the tergal arcs of the remaining somites being overlapped by the carapace and remaining undeveloped.

Examining the somites from behind forwards (for simplicity's sake), the last segment comes to be first described. This is the so-called "telson," which forms the last articulation of the abdomen, and never bears any appendages. For this reason, many authorities do not regard it as a somite, properly speaking, but simply as an azygous appendage—that is to say, as an appendage without a fellow. In the next segment (the last but one, or the last, of the abdomen, according to the view which is taken of the "telson"), there is a pair of natatory appendages, called "swimmerets." Each swimmeret (fig. 137, 2) consists of a basal joint, which articulates with the sternum, and is called the "protopodite" or propodite, and of two diverging joints, which are attached to the former; the outer of these being called the "exopodite," and the inner the "endopodite." In this particular segment, the exopodite and the endopodite are greatly expanded, so as to form powerful paddles, and the exopodite is divided into two by a transverse joint. In the succeeding somites of the abdomen—with the exception of the first, in which there is some modification—the appendages are in the form of swimmerets, essentially the same as those attached to the penultimate segment, and differ-

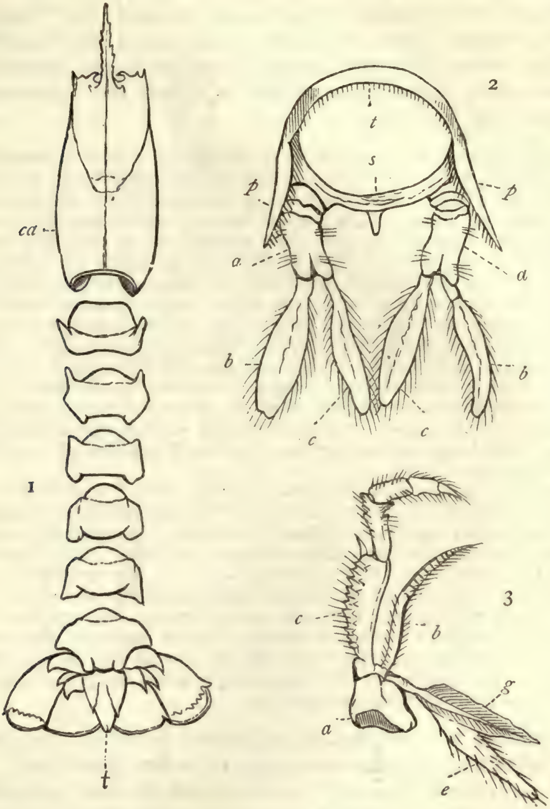

Fig. 137.—Morphology of Lobster. 1. Lobster, with all the appendages, except the terminal swimmerets, removed, and the abdominal somites separated from one another: *ca* Carapace; *t* Telson. 2. The third abdominal somite separated: *t* Tergum; *s* Sternum; *p* Pleura; *a* Protopodite; *b* Exopodite; *c* Endopodite. 3. One of the last pair of foot-jaws or maxillipedes: *e* Epipodite; *g* Gill; the other letters as before.

ing only in the fact that the exopodite and endopodite are much narrower, and the former is undivided (fig. 136). The last thoracic somite—immediately in front of the abdomen—carries a pair of the walking or ambulatory legs, each consisting of a short basal piece, or "protopodite," and of a long jointed "endopodite," the "exopodite" not being developed. The next thoracic segment carries another pair of ambulatory limbs, quite similar to the last, except for the fact that the protopodite bears a process which serves to keep the gills apart, and is termed the "epipodite." The succeeding segment supports a pair of limbs similar to the last in all respects, except that its extremities, instead of being simply pointed, are converted into nipping claws or "chelæ." The next segment of the thorax carries a pair of chelate limbs, just like the preceding; and the next is furnished with appendages, which are essentially the same in structure, but are much larger, constituting the great claws. The next two segments of the thorax, and the segment in front of these (by some looked upon as belonging to the head, by others as referable to the thorax), bear each a pair of modified limbs, which are termed "maxillipedes," or "foot-jaws." These are simply limbs with the ordinary structure of protopodite, exopodite, endopodite, and epipodite, but modified to serve as instruments of mastication, the hindmost pair being less altered than the two anterior pairs (fig. 137, 3). The next two somites carry appendages, which are in the form of jaws, and are termed respectively the first and second pairs of "maxillæ." Each consists of the parts aforementioned, but the epipodite of the first pair of maxillæ is rudimentary, whilst that of the second pair is large, and is shaped like a spoon. It is termed the "scaphognathite," and its function is to cause a current of water to traverse the gill-chamber by constantly bailing water out of it. The next segment carries the biting jaws or "mandibles;" each of which consists of a large protopodite, and a small endopodite, which is termed the "palp," whilst the exopodite is undeveloped. The aperture of the mouth is situated between the bases of the mandibles, bounded behind by a forked process, called the "labium," or "metastoma," and in front by a single plate, called the "labrum" (upper lip). The next segment bears the long antennæ, or feelers (fig. 136, *a′*), each consisting of a short protopodite, and a long, jointed, and segmented endopodite, with a very rudimentary exopodite. In front of the great antennæ is the next pair of appendages, termed the "antennules," or smaller antennæ (fig. 136, *a*), each composed of a protopodite, and a segmented endopodite and exopodite, which are nearly of equal size. Finally, attached to the first segment of the head are the eyes, each of which is borne upon an eye-stalk formed by the protopodite. The gill-chamber is formed by a great prolongation downwards of the pleuræ of the thoracic segments, and the gills are attached to the bases of the legs.

As regards the digestive system of the *Crustacea*, the alimentary canal is, with few exceptions, continued straight from the mouth to the aperture of the anus. There are no salivary glands, but a large and well-developed liver is usually present. A heart is generally, but not always, present. In most of the lower forms it is a long vasiform tube, very like the "dorsal vessel" of Insects. In the higher Crustaceans, the course of the circulation is as follows (fig. 138): The heart is a muscular sac, situated dorsally, beneath the carapace, and it gives origin to six arterial trunks, which convey the aerated blood to all parts of the body. The terminations of the arteries open into a series of irregular venous sinuses, whence the blood is collected into a principal ventral sinus, and distributed to the branchiæ, where it undergoes aeration. From the gills the now aerated blood is carried by a series of branchial vessels to a large sac, which is badly termed the "pericardium," and which envelops and surrounds the heart. The arterial blood gains access to the cavity of the heart by means of six pairs of valvular fissures, which allow of the ingress of the blood, but prevent regurgitation. A portion of the venous blood, however, is not sent to the branchiæ, but is returned directly, without aeration, to the pericardium; so that the heart finally distributes to the body a mixture of venous and arterial blood.

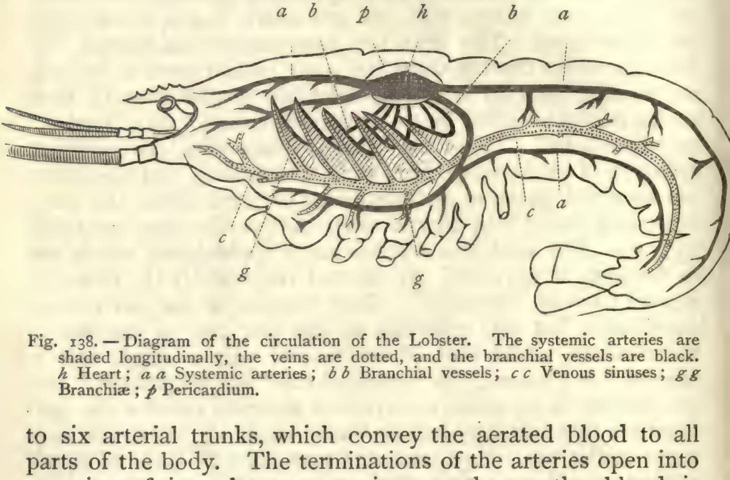

Fig. 138.—Diagram of the circulation of the Lobster. The systemic arteries are shaded longitudinally, the veins are dotted, and the branchial vessels are black. *h* Heart; *a a* Systemic arteries; *b b* Branchial vessels; *c c* Venous sinuses; *g g* Branchiæ; *p* Pericardium.

Distinct respiratory and circulatory organs may be altogether wanting; but, as a rule, distinct branchiæ are present. The exact form and structure of the gills differ in different cases, but their leading modifications will be alluded to in treating of the different orders.

TABULAR VIEW OF THE DIVISIONS OF THE CRUSTACEA.

Sub-class I. EPIZOA.
  Order 1. *Ichthyophthira.*
  " 2. *Rhizocephala.*
  " 3. *Cirripedia.*
    Sub-order 1. *Thoracica.*
    " 2. *Abdominalia.*
    " 3. *Apoda.*

Sub-class II. ENTOMOSTRACA.
  Order 6. *Ostracoda.* } *Legion*, Lophyropoda.
  " 7. *Copepoda.* }
  " 8. *Cladocera.* } *Legion*, Branchiopoda.
  " 9. *Phyllopoda.* }
  " 10. *Trilobita.* }
  " 11. *Merostomata.*

Sub-class III. MALACOSTRACA.
  Division A. EDRIOPHTHALMATA.
  Order 12. *Læmodipoda.*
  " 13. *Amphipoda.*
  " 14. *Isopoda.*
  Division B. PODOPHTHALMATA.
  Order 15. *Stomapoda.*
  " 16. *Decapoda.*
    Tribe *a. Macrura.*
    " *b. Anomura.*
    " *c. Brachyura.*

CHAPTER XXXI.

SUB-CLASS EPIZOA.

THE members of this sub-class are Crustaceans which in the adult state (except the males of some forms) are destitute of the power of locomotion, being fixed parasitically to the exterior of other animals or adherent to foreign bodies. The young are locomotive, and are provided with eyes and antennæ. Branchiæ are wanting or rudimentary.

ORDER I. ICHTHYOPHTHIRA.—*Adult parasitic, deformed, often with rudimentary limbs; mouth suctorial; respiratory organs wanting; females with external ovisacs. Larvæ locomotive, and undergoing retrograde metamorphosis.*

The members of this order (*Lernæa*, *Achtheres*, *Peniculus*, *Caligus*, *Argulus*, &c.) are attached in the adult condition to the skin, eyes, or gills of fishes, and when mature possess an elongated body, having a more or less distinct head, and in the females usually a pair of long, cylindrical ovisacs, depending from the extremity of the abdomen (fig. 139). Some adhere by a suctorial mouth, or by cephalic processes (*Cephaluna*); others are attached by a suctorial disc, developed at the extremities of the last pair of thoracic limbs, which are united together (*Brachiuna*); whilst in others (*Onchuna*) attachment is effected by hooks at the free extremities of the first pair of thoracic limbs (Owen).

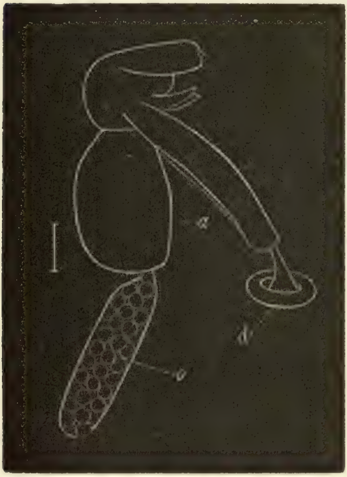

Fig. 139.—Female of *Achtheres Carpenteri*, magnified. The line placed alongside of the figure shows the real size. *a* Abdomen; *d* Disc of attachment developed upon the last pair of thoracic limbs; *o* Ovisac.

The males (fig. 140, *b*) are usually not attached, but adhere to the females, of which, from their much smaller size, they appear to be mere parasites. The chief anatomical peculiarities of the female are the following: The head is provided usually with a pair of jointed antennæ, and the body is divided into a cephalothorax and abdomen. The alimentary canal consists of a mouth, gullet, and intestine, terminating posteriorly in a distinct anus. The nervous system consists of a double ventral cord. There are no differentiated breathing-organs, and respiration is effected by the surface of the body.

The embryo (fig. 140, *a*) is free-swimming, and is provided with visual organs and locomotive appendages. The two sexes are now alike, and the conversion of the active embryo, or larva, into the swollen and deformed adult, must be regarded as an instance of "retrograde metamorphosis." In *Achtheres percarum* (fig. 140), as generally in the order, the primitive form of the young is a "Nauplius;"* but a wholly different larva, resembling the *Cyclops* in shape, but with fewer limbs and somites, is prepared within the Nauplius-skin, and is liberated by the rupture of the same.

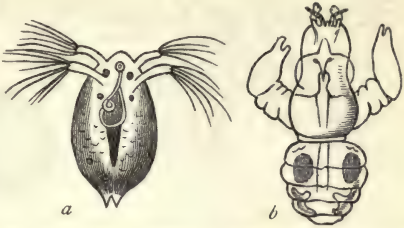

Fig. 140.—Ichthyophthira. *a* Free-swimming larva of *Achtheres percarum* in its first stage; *b* Adult male of the same. Enlarged. (After Owen.)

As regards their affinities, the *Ichthyophthira* are closely allied to the *Copepoda*, and may, indeed, be regarded as parasitic Copepods, having the mouth modified so as to form a suctorial tube or beak, resulting from the elongation of the labrum and labium. Within this are two stylets or lancet-shaped mandibles, used in piercing. The feet are often deformed by age, or wanting, but are primitively natatory. Not only does their developmental history bear out this view, but cases are known (in some *Lernææ*) in which the males do not undergo retrograde metamorphosis, but remain permanently in the condition of free Copepods.

ORDER II. RHIZOCEPHALA.—*Adult parasitic, attached by ramified roots (antennæ?). Body sac-like, unarticulated, without limbs. No mouth. Larva a locomotive "nauplius."*

The *Rhizocephala* constitute a peculiar group of Crustaceans, the adults of which are found attached parasitically to the abdomen of Crabs and Hermit-crabs. The body (fig. 141, B) is sac-like, and non-segmented, and consists of a muscular mantle in which no skeletal structures are developed, its only aperture being reproductive and closed by a sphincter. There are no limbs, sense-organs, or alimentary canal, but there are well-developed reproductive organs, each individual, according to Giard, being hermaphrodite. The sac-like body is kept in connection with its host by means of branched, root-like processes of attachment (fig. 141, B), which sink deeply into the tissues of the latter. These processes appear to correspond with the "cement-ducts" of the Cirripedes, and to be, therefore, really the homologues of the antennæ. By their means, the parasite draws nutriment from its host; and as similar hollow nutritive processes are developed on the "peduncle" of certain Barnacles (*Anelasma squalicola*), there are grounds for accepting Kossmann's view that the *Rhizocephala* are really to be regarded as a degraded group of the *Cirripedia*.

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* The name of "Nauplius" was given by O. F. Müller to the unsegmented ovate larva of the lower *Crustacea*, with a median frontal eye, but without a true carapace; and this name may be conveniently employed to designate all the larval forms which agree in these characters.

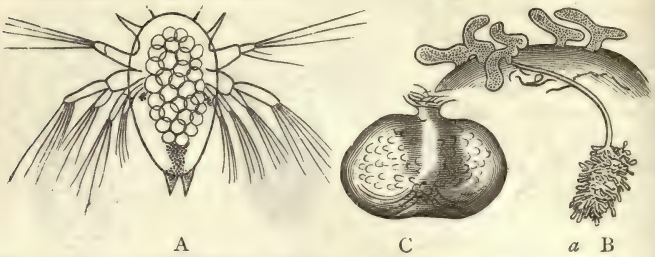

Fig. 141.—Morphology of *Rhizocephala*. A, First larval form of *Sacculina purpurea*, greatly enlarged. B, Young of *Peltogaster socialis* attached to the abdomen of a Hermit-crab; at *a* the root-like processes of attachment of one individual are shown. C, body of *Sacculina carcini*, of the natural size, the roots of attachment not shown. (A and B are after Fritz Müller.)

The embryos of the *Rhizocephala* (fig. 141, A) are at first "naupliiform," with an ovate unsegmented body, an unpaired median eye, and a dorsal shield or carapace. The abdomen terminates in a movable caudal fork, and there is neither mouth nor alimentary canal. In their second stage (as so-called "pupæ"), the young of the *Rhizocephala* are enclosed in a bivalve shell, the foremost pair of limbs constitute peculiar organs of adhesion ("prehensile antennæ" of Darwin), the two following pairs of limbs are cast off, and six pairs of powerful biramose natatory feet are formed on the thorax. There is still no mouth. The "pupæ" now attach themselves to the abdomen of Crabs, *Porcellanæ*, and Hermit-crabs; they remain astomatous; "they lose all their limbs completely, and appear as sausage-like, sack-shaped, or discoidal excrescences of their host, filled with ova; from the point of attachment closed tubes, ramified like roots, sink into the interior of the host, twisting round its intestine, or becoming diffused amongst the sack-like tubes of its liver. The only manifestations of life which persist in these *non plus ultras* in the series of retrogressively metamorphosed Crustacea are powerful contractions of the roots, and an alternate expansion and contraction of the body, in consequence of which water flows into the brood-cavity, and is again expelled through a wide orifice." (Fritz Müller).

ORDER III. CIRRIPEDIA.—*Adult attached, enclosed in an integumentary sac, within which a many-valved shell is typically developed. Antennæ modified for adhesion. Abdomen rudimentary. Limbs usually present, in the form of multiarticulate cirri. Sexes generally united. Young locomotive.*

This sub-class includes, amongst others, the common Acorn-shells and the Barnacles or Goose-mussels. All the *Cirripedia* are distinguished by the fact, that in the adult condition they are permanently fixed to some solid object by the anterior extremity of the greatly metamorphosed head; the first three cephalic segments being much developed, and enclosing the rest of the body. The larva is free and locomotive, and the subsequent attachment, and conversion into the fixed adult, is effected by means of a peculiar secretion, or cement, which is discharged through the antennæ of the larva, and is produced by a special cement-gland, which is really a portion of the ovary. In the *Cirripedia*, therefore, the head of the adult is permanently fixed to some solid object, and the visceral cavity is protected by an articulated calcareous shell, or by a coriaceous envelope. The posterior extremity of the animal is free, and can be protruded at will through the orifice of the shell. This extremity consists of the rudimentary abdomen, and of six pairs

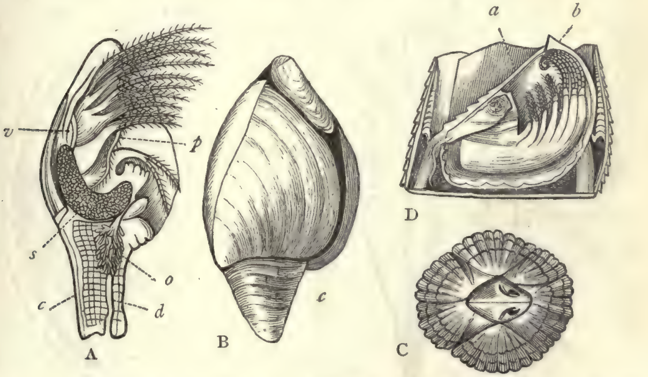

Fig. 142.—Morphology of Cirripedia. A, *Lepas pectinata*, one of the Barnacles, one side of the shell being removed, enlarged four times: *c* Peduncle; *d* Cement-duct; *o* Ovary; *s* Ovisac; *v* Vas deferens; *p* Penis. B, *Pæcilasma fissa*, enlarged five times; *c* Peduncle. C, *Balanus balanoides*, viewed from above, of the natural size. D, *Balanus tintinnabulum*, with the shell on one side removed to show the animal: *a* One of the valves ("scutum") of the operculum; *b* Another valve ("tergum") of the operculum. (After Darwin and Pagenstecher.)

of forked, cirrated limbs, which are attached to the thorax, and serve to provide the animal with food. The two more important types of the *Cirripedia* are the Acorn-shells (*Balanidæ*) and the Barnacles (*Lepadidæ*). In the former the animal is sessile, the larval antennæ, through which the cement exudes, being embedded in the centre of the membranous or calcareous "basis" of the shell. In the latter the animal is stalked, and consists of a "peduncle" and a "capitulum." The peduncle consists of the anterior extremity of the body, with the larval antennæ, usually cemented to some foreign body. The capitulum is supported upon the peduncle, and consists of a case composed of several calcareous plates, united by a membrane, enclosing the remainder of the animal.

As regards the development of the *Cirripedia*, the larva has the form of a "Nauplius" (fig. 143, A), with an unsegmented, pyriform body, a median eye, and a dorsal carapace. During its life as a Nauplius, the young moults several times (seven times in *Lepas fascicularis*, which is here taken as exemplifying the development of the Cirripedia in general); and these various castings of its integuments are accompanied with material changes of form.

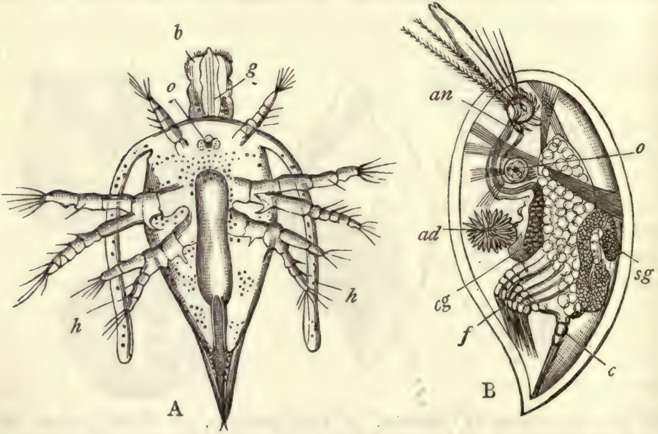

Fig. 143.—Development of *Lepas fascicularis*. A, Early stage of the Nauplius, showing the three pairs of appendages, of which the hinder two pairs are bifurcate: *o* Eye-spot; *b* Labrum; *g* Gullet; *h h* Lateral horns. B, the free-swimming Cypris-stage or "pupa," after the sixth moult, the antennæ and feet retracted within the shell: *an* Antenna, with its suctorial disc, traversed by the duct of the cement-gland (*cg*); *sg* Shell-gland; *o* Eye; *ad* Adductor-muscle; *f* Feet; *c* Caudal process. Both figures are greatly enlarged. (After Von Willemöes-Suhm.)

When fully grown, the Nauplius has an oval or pyriform body, enclosed in a carapace, provided with long caudal and dorsal spines. There are three pairs of limbs, of which the first pair (representing the antennæ) are undivided, while the two hinder pairs (fig. 143) are bifid, and all carry natatory bristles. There is a very large labrum (fig. 143, *b*) placed in front of the mouth, and there is a well-developed alimentary tube, which terminates by a distinct anus at the root of the caudal spine. There is at first merely a simple central eye; but in the adult Nauplius, two compound lateral eyes are developed in addition. Ultimately, the Nauplius passes into its second condition or "Cypris-stage" (fig. 143, B), when it is often spoken of as a "pupa." It is now enclosed in an oval, bivalved, mussel-shaped shell, with an opening along the ventral margin. The second and third pairs of the appendages of the Nauplius have now disappeared, and the first pair of appendages constitute strong four-jointed antennæ, the last segment of which is disc-shaped, and is pierced centrally by a pore, which is the opening of the excretory duct of the "cement-glands," these organs being situated at the bases of the antennæ. The thorax has developed upon its sides six pairs of forked natatory limbs; and the abdomen is rudimentary, three-jointed, with terminal forked swimming-appendages. The pupa does not feed, but is nourished by means of an extensive accumulation of fatty matter, which had been stored up by the Nauplius in the cephalic and dorsal regions of the body; while the great labrum of the latter is now very much reduced in size.

After a brief natatory life, the pupa fixes itself by means of the disc-segments of the antennæ to some foreign body, such as a rock, a piece of drift-wood, the skin of a Cetacean, a Sponge, the carapace of a Turtle, or the colony of an Oceanic Hydrozoön. The "cement-glands," which, as shown by Darwin, are "part of and continuous with the branching ovaria," secrete copiously an adhesive cement, which is poured forth through the central apertures of the antennal discs, and by means of which the animal is firmly and finally fastened down to the object to which it in the first place attached itself. The body now becomes enclosed in a multivalve calcareous "test," produced by a special shell-gland. The organs of the mouth become fully developed, and the lateral eyes of the locomotive pupa disappear altogether. Lastly, the six pairs of natatory limbs of the Cypris-stage are replaced by the six forked and multisegmentate "cirri" of the adult; while the base of the abdomen carries the penis, in the form of a proboscidiform appendage.

The form of the adult, as already said, differs considerably, but the two most important types are those presented respectively by the Sessile and by the Pedunculated *Cirripedia.*

In the symmetrical Sessile Cirripedes or *Balanidæ,* commonly known as Acorn-shells (fig. 142, C, D), the animal is protected by a calcareous shell, formed by calcifications within the walls of the first three cephalic segments. The animal is placed within the shell, head downwards, and is fixed to the centre of a shelly or membranous plate, which closes the lower aperture of the shell, and which is termed the "basis." The "basis" is fixed by its outer surface to some foreign object, and is sometimes compact, sometimes porous. Above the basis rises a limpet-shaped, conical, or cylindrical shell, which is open at the top, but is capable of being completely closed by a pyramidal lid or "operculum." Both the shell itself and the operculum are composed of calcareous plates usually differing from one another in shape, and distinguished by special names. Within the shell the animal is fixed, head downwards. The thoracic segments, six in number, bear six pairs of limbs, each of which consists of a jointed protopodite and a much-segmented exopodite and endopodite, both of which are bristled, and constitute the so-called "cirri," from which the name of the sub-class is derived. These twenty-four cirri—"the glass hand" of the *Balanus*—are in incessant action, being protruded from the opening of the shell, and again retracted within it, constantly producing currents of water, and thus bringing food to the animal. There are no specialised respiratory organs in the family of the *Balanidæ*. *Balani* sometimes attain a very considerable size, and *Balanus psittacus* is largely eaten on the coast of Chili.

The remaining family of the Sessile Cirripedes is that of the *Verrucidæ*, comprising only the single genus *Verruca*. In many respects the *Verrucidæ* approach the *Balanidæ*, but the shell is composed of six valves only, and is unsymmetrical, whilst the scuta and terga (forming the operculum), though movable, are not furnished with a depressor muscle.

In the Barnacles (*Lepadidæ*), the anterior extremity of the animal is enormously elongated, forming, with the prehensile antennæ, the cement-ducts, and their exudation, a long stalk or peduncle, whereby the animal is attached to some solid object. The peduncle is cylindrical, of varying length, flexible, and furnished with proper muscles. In some species it is naked, but in others it is furnished with calcareous scales. At its free extremity the peduncle bears the "capitulum," which corresponds to the shell of the Balanoids, and is composed of various calcareous plates, united together by a membrane, moved upon one another by appropriate muscles, and protecting in their interior the body of the animal with its appendages. The thorax and limbs resemble those of the *Balanus*; but "slender appendages, which from their position and connections are homologous with the branchiæ of the higher *Crustacea*, are attached to, or near to, the bases of a greater or less number of the thoracic feet, and extend in an opposite direction outside the visceral sac" (Owen).

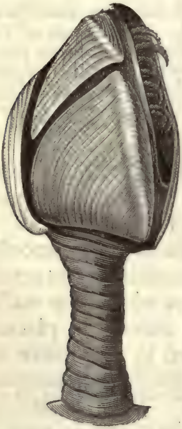
Fig. 144.—*Lepas anatifera*, the common Barnacle.

All the *Balanidæ* are hermaphrodite, and this is also the case with most of the *Lepadidæ*, but some extraordinary exceptions occur in this latter order. Thus, in some species of *Scalpellum* the individual forming the ordinary shell is female, and each female has two males lodged in transverse depressions within the shell. These males "are very singular bodies; they are sac-formed, with four bead-like rudimental valves at their upper ends; they have a conspicuous internal eye; they are absolutely destitute of a mouth, or stomach, or anus; the cirri are rudimental and furnished with straight spines, serving apparently to protect the entrance of the sac; the whole animal is attached like the ordinary Cirripede, first by the prehensile antennæ, and afterwards by the cementing substance. The whole animal may be said to consist of one great sperm-receptacle, charged with spermatozoa; as soon as these are discharged, the animal dies."

"A far more singular fact remains to be told; *Scalpellum vulgare* is, like ordinary Cirripedes, hermaphrodite, but the male organs are somewhat less developed than is usual; and as if in compensation, several short-lived males are almost invariably attached to the occludent margin of both scuta. . . . I have called these beings *complemental males*, to signify that they are complemental to an hermaphrodite, and that they do not pair like ordinary males with simple females" (Darwin).

As regards their distribution, the *Balanoids* are shallow-water forms, and *Balanus* itself is cosmopolitan in its range, though, geologically, quite a modern genus. The Lepadoids are not only found attached to floating bodies, dead or alive, but also extend to great depths. *Scalpellum*, which is a common Cretaceous genus, goes down to 3000 fathoms. *Alcippe* (which is without a shell and has only three pairs of feet), bores holes in the shells of Gasteropods.

DIVISIONS OF CIRRIPEDIA.—(AFTER DARWIN.)

SUB-ORDER I. THORACICA.

Carapace, either a capitulum on a pedicle, or an operculated shell with a basis. *Body*, formed of six thoracic segments, generally furnished with six pairs of limbs; abdomen rudimentary, but often bearing caudal appendages.

Fam. 1. *Balanidæ.*

Sessile, without a peduncle; scuta and terga (forming the *operculum*) provided with depressor muscles; the rest of the valves immovably united together.

Fam. 2. *Verrucidæ.*

Sessile. Shell asymmetrical, with scuta and terga, which are movable, but not furnished with a depressor muscle.

Fam. 3. *Lepadidæ.*

Pedunculated. *Peduncle* flexible, provided with muscles. Scuta and terga, when present, not furnished with a depressor muscle. Other valves, when present, not united into a single immovable case.

SUB-ORDER II. ABDOMINALIA.

Carapace, flask-shaped; body formed of one cephalic, seven thoracic, and three abdominal segments, the latter bearing three pairs of cirri, but the thoracic segments being without limbs.

Genus—*Cryptophialus*.

SUB-ORDER III. APODA.

Carapace, reduced to two separate threads serving for attachment. *Body* consisting of one cephalic, seven thoracic, and three abdominal segments, all destitute of cirri. Mouth suctorial.

Genus—*Proteolepas*.

CHAPTER XXXII.

SUB-CLASS ENTOMOSTRACA.

SUB-CLASS III. ENTOMOSTRACA (*Gnathopoda*, Woodward).—The term *Entomostraca* has been variously employed, and few authorities include exactly the same groups of the *Crustacea* under this name. By most the division is simply defined as including all those *Crustacea* in which the segments of the thorax and abdomen, taken together, are more or fewer than fourteen in number—the parasitic *Epizoa* and the *Cirripedia* being excluded. By Professor Rupert Jones the following definition of the *Entomostraca* has been given:—

"Animal, aquatic, covered with a shell or carapace, of a horny consistence, formed of one or more pieces, in some genera resembling a cuirass or buckler, and in others a bivalve shell, which completely or in great part envelops the body and limbs of the animal. In other genera the animal is invested with a multivalve carapace, like jointed plate-armour; the branchiæ are attached either to the feet or to the organs of mastication; the limbs are jointed, and more or less setiferous. The animals, for the most part, undergo a regular moulting or change of shell, as they grow; in some cases this amounts to a species of transformation."

The *Entomostraca* are divided into two great divisions, or "legions," the *Lophyropoda* and the *Branchiopoda*, with which the order *Merostomata* may be conveniently considered.

DIVISION A. LOPHYROPODA.—The members of this division possess few branchiæ, and these are attached to the appendages of the mouth. The feet are few in number, and mainly subserve locomotion; the carapace is in the form either of a shield protecting the cephalothorax, or of a bivalve shell enclosing the entire body. The mouth is not suctorial, but is furnished with organs of mastication.

This division comprises the two orders *Ostracoda* and *Copepoda.*

ORDER I. OSTRACODA.—*Small Crustaceans having the entire body enclosed in a shell or carapace, which is composed of two valves united along the back by a membrane. The branchiæ are attached to the posterior jaws, and there are only two or three pairs of feet, which subserve locomotion, but are not adapted for swimming.* A distinct heart is sometimes present (*Cypridina*), but is more usually wanting (*Cypris* and *Cythere*).

Little is known of the development of the *Ostracoda*, but the young of *Cypris* are said to be "shell-bearing Nauplius forms" (Claus), possessing only the three anterior pairs of limbs, but protected by a bivalve shell. As in other Nauplii, the third pair of limbs, though now locomotive, are ultimately transformed into the mandibles. They pass through several stages, with complete moults, before arriving at sexual maturity. The young of *Cythere*, on the other hand, have at birth the two pairs of antennæ and two pairs of jaws, with three pairs of rudimentary abdominal limbs.

The order includes the *Cyprides* (fig. 145, *a*), which are of almost universal occurrence in fresh water. The common *Cypris* is completely protected from its enemies by a bivalve carapace, which it can open and shut at will, and out of which it can protrude its feet. The closure of the carapace is effected by means of an adductor muscle. Locomotion is mainly effected by means of a pair of caudal appendages. The *Cypris* is extremely prolific, and a single impregnation appears to last

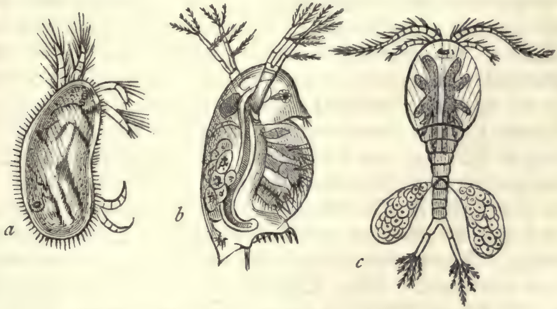

Fig. 145.—Fresh-water Entomostraca. *a Cypris tris-striata: b Daphnia pulex; c Cyclops quadricornis.*

the female for its entire lifetime. Young females, produced in this way, are also capable for some generations of producing fresh individuals without the influence of a male (parthenogenesis).

The marine Ostracoda are mostly shallow-water forms, but there are deep-sea types which attain a comparatively gigantic size (nearly an inch in length).

ORDER II. COPEPODA.—*Small Crustaceans, having the head and thorax covered by a carapace, and furnished with five pairs of natatory feet. Usually there are two caudal locomotive appendages.* A distinct heart is sometimes absent (as in the *Cyclopidæ*) but is sometimes present. Both marine and fresh-water Copepods are known.

The larvæ of the Copepods are Naupliiform, with unpaired eyes, three pairs of limbs (the future antennæ and mandibles), and two terminal setæ. Next the maxillæ are produced, and then three other pairs of limbs (the foot-jaws and the two front pairs of natatory feet). At the next moult, the larva assumes the *Cyclops* form, but has at first much fewer limbs and somites.

In the *Cyclops* (fig. 145, *c*), which is one of the commonest of the "Water-fleas," the cephalothorax is protected superiorly by a carapace, and the abdominal somites are conspicuous. In front of the head is situated a single large eye, behind which are the great antennæ and the antennules. The feet are five pairs in number, each consisting of a protopodite and a segmented exopodite and endopodite, usually furnished with hairs, and forming an efficient swimming apparatus. The young pass through a metamorphosis, and are not capable of reproducing the species until after the third moult or change of skin. The female *Cyclops* carries externally two ovisacs, in which the ova remain till they are hatched. A single congress with the male is apparently sufficient to fertilise the female for life.

The *Copepoda*, or Oar-footed Crustaceans, are all of small size, and are of common occurrence in fresh water in all parts of Europe. Many forms also live in the sea, sometimes in immense numbers. Thus *Cetochilus* is so abundant in the North and South Atlantic, as to communicate a ruddy tinge to the ocean, and to serve as one of the principal articles of diet of the whale. By good authorities the *Ichthyophthira* are regarded as merely *Copepoda* peculiarly modified to suit a life of parasitism.

DIVISION B. BRANCHIOPODA.—The Crustaceans included in this division have many branchiæ, and these are attached to the legs, which are often numerous, and are formed for swimming. In other cases the legs themselves are flattened out so as to form branchiæ. The body is either naked, or is protected by a carapace, which may enclose either the entire body, or the head and thorax only. The mouth is provided with organs of mastication.

The *Branchiopoda* comprise the *Cladocera*, the *Phyllopoda*, and probably the *Trilobita*, though this order departs in many respects from the first two groups. The *Merostomata* may be considered along with these, though these, too, are in many respects peculiar.

ORDER I. CLADOCERA.—The members of this order are *small Crustaceans, which have a distinct head, and have the whole of the remainder of the body enclosed within a bivalve carapace, similar to that of the Ostracoda. The feet are few in number (usually four, five, or six pairs), and are mostly respiratory, carrying the branchiæ. Two pairs of antennæ are present, the larger pair being of large size, branched, and acting as natatory organs.* The *Cladocera* quit the egg with the full number of limbs proper to the adult.

In the *Daphnia pulex* (fig. 145, *b*), or "branched-horned Water-flea," which occurs commonly in our ponds, the body is enclosed in a bivalve shell, which is not furnished with a hinge posteriorly, and which opens anteriorly for the protrusion of the feet. The head is distinct, not enclosed in the carapace, and carrying a single eye. The mouth is situated on the under surface of the head, and is provided with two mandibles and a pair of maxillæ. The gills are in the form of plates, attached to the five pairs of thoracic legs. The males are very few in number, compared with the females, and a single congress is all that is required to fertilise the female for life. Not only is this the case, but the young females produced from the original fecundated female are able to bring forth young without having access to a male. Two kinds of eggs occur in *Daphnia*. In the first of these, or "summer eggs," the ova (from ten to fifty in number) are deposited in an open space between the valves, and are retained there until the young are ready to be hatched. In the second of these, or "winter eggs," which alone are fecundated, the ova (generally two in number) are placed in a peculiar receptacle, which is formed on the back of the carapace, and is called the "ephippium" or saddle. After a time the ephippium is cast off, and floats about till spring, when its contained eggs are hatched by the warmer temperature of the water.

ORDER II. PHYLLOPODA.—*Crustacea, mostly of small size, the carapace protecting the head and thorax, or the body entirely naked. Feet numerous, never less than eight pairs, mostly foli-*

aceous or leaf-like, branchial in function. The eyes sometimes confluent, sometimes distinct and sub-pedunculate. There are two horny mandibles without palps, and the first pair of feet are oar-like, with setiform terminal appendages. The remaining feet are branchial, and adapted for swimming. The Phyllopods undergo a metamorphosis, the youngest forms being "Nauplii." In *Nebalia* (fig. 147, C), however, which is the only marine Phyllopod, "Zoea-stages" are superadded as well.

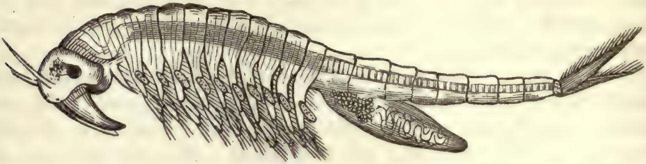

Fig. 146.—Phyllopoda. Fairy Shrimp (*Chirocephalus*, or *Branchipus, diaphanus*). After Baird.

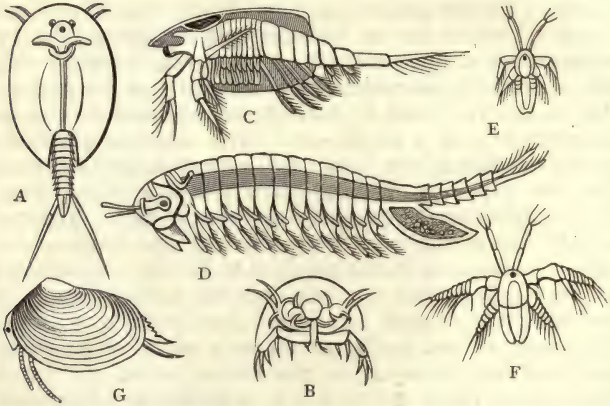

Fig. 147.—Morphology of Phyllopoda. A, *Lepidurus Angassi*, viewed dorsally. B, Under side of head of the same. C, *Nebalia bipes*, one side of the carapace being removed, so as to show the branchial feet. D, *Branchipus stagnalis*, female. E and F, Young stages of the same. G, A magnified specimen of *Estheria*, in its living state.

The *Phyllopoda* are chiefly interesting from their affinity to the extinct Trilobites. In the typical genera *Limnadia* and *Apus* the body is protected by a carapace, which is bivalve in the former and shield-like in the latter. In *Limnadia* the carapace covers the greater part of the body, and opens along the ventral margin. There are from eighteen to thirty pairs of membranaceous and respiratory feet. In *Apus* the carapace is clypeiform and covers a portion of the abdomen; and there are sixty pairs of feet, of which all but the first pair are foliaceous. *Apus* is gregarious, fresh-water in habit, and often found in great numbers in pools and ditches in Europe. The different species of *Branchipus* (figs. 146 and 147, D) have the transparent body unprotected by any carapace, and are found in ponds and swamps in various parts of the world. The various "Brine-shrimps" (*Artemia*) are found inhabiting the brine-pans in salt-works, or occur in salt-lakes in both hemispheres, being especially abundant in Great Salt Lake in Utah.

In *Estheria* (fig. 147, G) the body is protected by a bivalve, sub-ovate carapace, which is extremely like the shell of a Bivalve Mollusc, not only in shape and appearance, but also in having the valves joined at their beaks dorsally, and marked with concentric lines of growth. The species live in fresh or brackish water. In *Nebalia* (fig. 147, C), the only marine type of the order, there is a bivalved carapace, which is furnished with a beak or "rostrum," and the eyes are pedunculated. There are two pairs of antennæ, and eight pairs of leaf-like respiratory feet, followed by a series of natatory feet. There is no metamorphosis. *Nebalia* has decided affinities with the Stomapods, and perhaps is not properly referable to the *Phyllopoda*.

ORDER III. TRILOBITA.—This order is entirely extinct, none of its members having survived the close of the Palæozoic period. The Trilobites are *Crustaceans in which the body is usually more or less distinctly trilobed; there is a cephalic shield, usually bearing a pair of sessile compound eyes; the thoracic somites are movable upon one another, and are very variable in number; the abdominal segments are coalescent, and form a caudal shield; there is a well-developed upper lip or "hypostome."*

As regards the general structure of the Trilobites, the body was protected by a well-developed shell or "crust," which covered the whole dorsal surface of the body, and which usually exhibits more or less markedly a division into three longitudinal lobes (fig. 148), from which the name of the order is derived. The crust is composed of a cephalic shield, generally crescentic in shape, a variable number of free and movable rings, constituting the thorax, and a caudal shield or "pygidium," the rings of which are more or less completely anchylosed. On the under surface of the head-shield in front, there is situated a forked or oval upper lip or "labrum," which resembles in form the labrum of the Phyllopodous genus *Apus*. Recent researches by Mr C. D. Walcott have also considerably increased our knowledge of the condition of the under surface of the body in the Trilobites. This observer, namely, has shown that the visceral cavity of the Trilobites (fig. 149, *b*) was bounded inferiorly by a thin membrane, which is attached to the lower margin of the dorsal crust all round. This ventral membrane was strengthened by calcified arches, which in turn supported the appendages beneath. As to these latter our knowledge is not yet complete, but we know that in some forms there existed a row of articulated appendages on each side of the middle line below. The thoracic appendages seem to have been slender five-jointed legs, in which the terminal segment forms a pointed claw, and the basal segment carries a jointed appendage, regarded by Mr Walcott as homologous with the

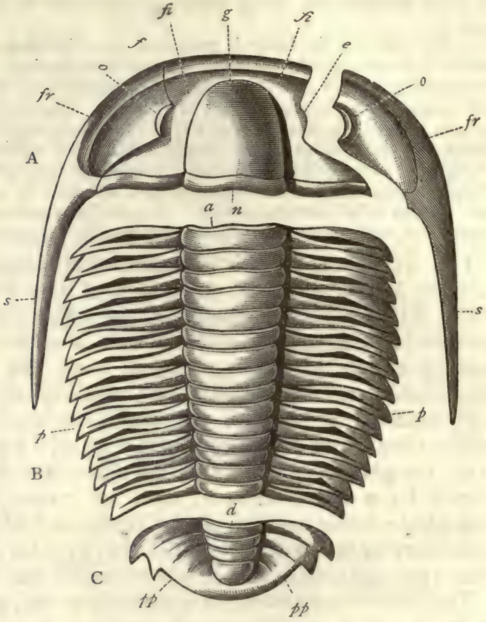

Fig. 148.—The skeleton of a Trilobite (*Angelina Sedgwickii*), partially dissected. A, Head-shield. B, Movable rings of the thorax. C, Tail or abdomen. *g* Glabella, in this species without furrows; *fi* Fixed cheeks; *e* Eye-lobe; *o* Eye; *f* Facial suture; *fr* Free cheeks: *s* Head-spines; *p* Pleuræ; *pp* Anchylosed pleuræ of pygidium.

"epipodite" of many recent Crustaceans. On each side of the thoracic cavity there is, also, attached a row of bifid spiral appendages (fig. 149, *e*), of the nature of gills; and branchial appendages were probably attached to the bases of the thoracic limbs as well. With regard to the appendages of the head, the mouth is situated behind the hypostome, and is bounded by four pairs of jointed manducatory appendages, the basal joints of which are, partly or wholly, modified to act as jaws.

The cephalic shield of a typical Trilobite is more or less completely semicircular (fig. 148), and is composed of a central and of two lateral pieces, of which the two latter may, or may not, be united together in front of the former.

The median portion is usually elevated above the remainder of the cephalic shield, and is called the "glabella;" it protected the region of the stomach, and is usually divided into from three to four lobes by lateral grooves. At each side of the glabella, and continuous with it, is a small semicircular area, called the "fixed cheek." The glabella, with the "fixed cheeks," is separated from the lateral portions of the cephalic shield—termed the "movable" or "free cheeks"—by a peculiar suture or line of division, which is known as the "facial suture," and is quite unknown amongst recent *Crustacea*, except for a faint indication in the *Limulus*, and more or less doubtful traces in certain other forms. The movable cheeks bear the eyes, which are generally crescentic or reniform in shape, are rarely pedunculated (being never supported upon movable foot-stalks), and consist of an aggregation of facets covered by a thin cornea. The facial sutures may join one another in front of the glabella—in which case the free cheeks will form a single piece; or they may cut the anterior margin of the shield separately—in which case the free cheeks will be discontinuous. The posterior angles of the free cheeks are often produced into long spines.

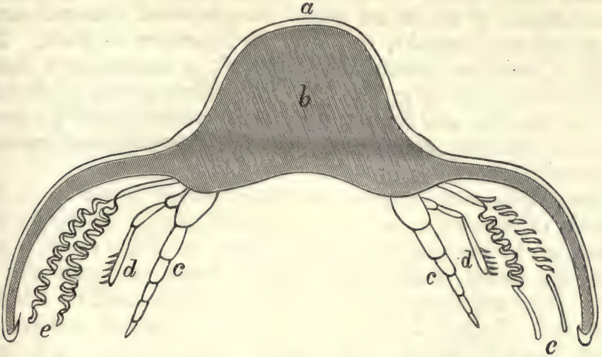

Fig. 149.—Transverse section of the thorax of *Calymene senaria*, partially restored (after C. D. Walcott). *a* Dorsal crust; *b* Visceral cavity, continued laterally to the pleural margins of the dorsal crust; *c* Legs, restored; *d* Epipodite; *e* Spiral gills. Enlarged six times.

Behind the cephalic shield comes the thorax, composed of a variable number of segments, which are not soldered together, but are capable of free motion upon one another, so as to allow the animal, in many cases, to roll itself up after the manner of a wood-louse or hedgehog. The thorax is usually strongly trilobed, and each thorax-ring shows the same trilobation, being composed of a central, more or less strongly convex, portion, called the "axis," and of two flatter side-lobes, called the "pleuræ."

The "pygidium," or "tail," is usually trilobed also, and, like the thorax, consists of a median axis and of a marginal limb, the composition of the whole out of anchylosed segments being shown by the existence of axial and pleural grooves.

ORDER IV. MEROSTOMATA.—The members of this order are *Crustacea*, often of gigantic size, in which the mouth is furnished with mandibles and maxillæ, the terminations of which become walking or swimming feet and organs of prehension.

This order comprises the recent King-crabs, and the extinct *Pterygoti* and *Eurypteri*.

SUB-ORDER I. XIPHOSURA.—"*Crustacea having the anterior segments welded together to form a broad convex buckler, upon the dorsal surface of which are placed the compound eyes and ocelli, the former sub-centrally, the latter in the centre in front. The mouth is furnished with a small labrum, a rudimentary metastoma and six pairs of appendages. Posterior segments of the body more or less free, and bearing upon their ventral surfaces a series of broad lamellar appendages; the telson, or terminal segment, ensiform*" (Henry Woodward).

The *Xiphosura* include no other recent forms than the *Limuli* (King-crabs, or Horse-shoe Crabs). They are distinguished by the possession of *six pairs of chelate limbs, placed round the mouth, having their bases spinous, and officiating as jaws.* The anterior portion of the body is covered by a broad horse-shoe-shaped buckler (fig. 150), the upper surface of which bears a pair of larval and a pair of compound eyes. On the lower surface of the carapace is placed the aperture of the mouth, surrounded by six pairs of limbs, the bases of which are spinous and officiate as jaws, whilst their terminations are converted into chelæ or nipping-claws. The first pair of appendages is placed in front of the mouth, and has been generally said to represent the antennæ; but according to Milne-Edwards they are not supplied with nerves from the cerebral ganglia, and therefore cannot be of this nature. Behind the cephalic buckler comes a second shield, composed of six amalgamated segments, below which are carried the reproductive organs and branchiæ, the former protected by a thoracic plate or "operculum," the latter borne by five pairs of lamellar appendages. Lastly, articulated to the posterior margin of the abdominal shield, is a long sword-like spine or "telson" (fig. 150, *t*). The circulatory system of *Limulus* is of a very high type, though the heart is tubular. The venous blood, instead of being contained in the mere interspaces and lacunæ between the tissues, is to a large extent confined within proper vessels. A remarkable peculiarity, also, is that the ventral nerve-cord is enclosed within the abdominal artery, and most of the nerves are similarly ensheathed within the arteries.

The eggs of *Limulus* are laid in the sand, and are fertilised by the male. Just prior to the time of hatching, six segments can be recognised in the cephalothorax; the abdomen consists of nine well-marked somites; the bases of the legs are hardly spinose; and the abdominal spine is quite rudimentary. In this stage (fig. 152), the larva closely resembles some of the

Trilobites, such as *Trinucleus* and *Asaphus*. After hatching, the previously existing segmentation is soon obliterated, and, three or four weeks later, the telson assumes the ensiform shape characteristic of the adult. According to the views of Van Beneden, the development of *Limulus* so closely resembles that of the Scorpions, that the former should properly be removed from the *Crustacea*, and placed in the *Arachnida*.

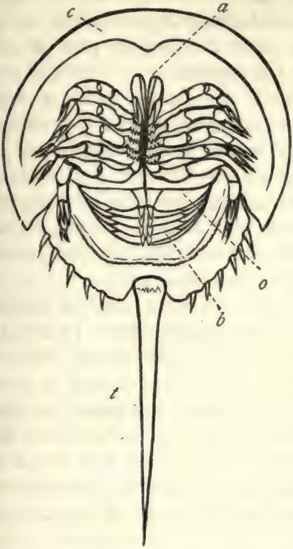

Fig. 150.—Xiphosura. *Limulus polyphemus*, viewed from below. *c* The cephalic shield carrying the sessile eyes upon its upper surface; *o* "Operculum," covering the reproductive organs; *b* Branchial plates; *a* First pair of antennæ (antennules) ending in chelæ. Below these is the aperture of the mouth, surrounded by the spiny bases of the remaining five pairs of appendages, which are regarded by Woodward as being respectively, from before backwards, the great antennæ, the mandibles, the first maxillæ, the second maxillæ, and a pair of maxillipedes. All have their extremities chelate.

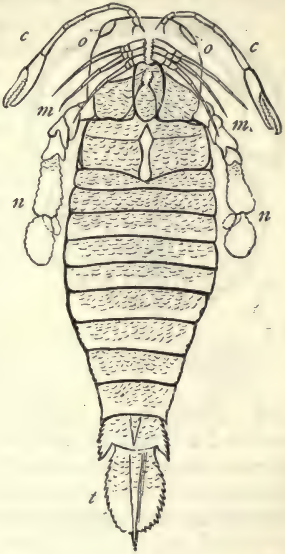

Fig. 151.—Eurypterida. *Pterygotus Anglicus*, restored (after H. Woodward). *c c* Chelate antennæ; *o o* Eyes situated at the anterior margin of the carapace; *m m* The mandibles, and the first and second maxillæ; *n n* The maxillipedes—the basal margins of these are serrated, and are drawn as if seen through the metastoma or post-oral plate, which serves as a lower lip. Immediately behind this is seen the operculum or thoracic plate which covers the two anterior thoracic somites. Behind this are five thoracic and five abdominal somites, and lastly there is the telson (*t*).

The King-crabs are found in the Indian and Japanese seas, on the coasts of North America, and in the Antilles. They sometimes attain a large size, and both the eggs and the flesh are eaten by the Malays.

SUB-ORDER 2. EURYPTERIDA.—"*Crustacea with numerous,* *free, thoracico-abdominal segments, the first and second (?) of which bear one or more broad lamellar appendages upon their ventral surface, the remaining segments being devoid of appendages; anterior rings united into a carapace, bearing a pair of larval eyes (ocelli) near the centre, and a pair of large marginal or sub-central eyes: the mouth furnished with a broad post-oral plate, or metastoma, and five pairs of movable appendages, the posterior of which form great swimming-feet: the telson, or terminal segment, extremely variable in form; the integment characteristically sculptured"* (Henry Woodward).

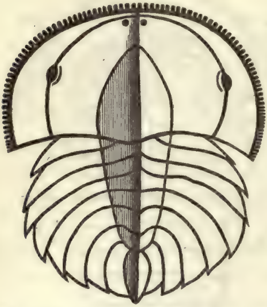
Fig. 152.—Larva of *Limulus* on hatching, greatly enlarged. (After Dohrn.)

The *Eurypterida* are all extinct, and are entirely confined to the Palæozoic period. Many of them attained to a comparatively gigantic size; *Pterygotus Anglicus* (fig. 151) being supposed to have reached a length of probably six feet. In their characters they present many larval features; resembling the larvæ of the *Decapoda* especially in the fact that all the free somites of the abdomen (except the two anterior ones) were totally devoid of appendages.

CHAPTER XXXIII.

MALACOSTRACA.

Sub-class IV. Malacostraca (*Thoracipoda*, Woodward).—The *Crustacea* of this sub-class are distinguished by the possession of a generally *definite* nnmber of body-segments; seven somites going to make up the thorax, and an equal number entering into the composition of the abdomen (counting, that is, the telson as a somite). The *Malacostraca* are divided into two primary divisions, termed respectively the *Edriophthalmata* and the *Podophthalmata*, according as the eyes are sessile or are supported upon eye-stalks.

Division A. Edriophthalmata.—This division comprises those *Malacostraca* in which the eyes are sessile, and the body is mostly not protected by a carapace. It comprises the three orders, *Læmodipoda*, *Isopoda*, and *Amphipoda*. The eyes are generally compound, but sometimes simple, and are placed on the sides of the head. The head is almost always distinct from the body, and the mandibles are often furnished with a palp. Typically there are seven pairs of feet in the adult, hence this division is called *Tetradecapoda* by Agassiz. In certain Isopods (*Tanais*) alone is there a carapace.

ORDER I. LÆMODIPODA.—*Small Crustaceans, with a rudimentary abdomen, the first two segments of the thorax amalgamated with the head, and carrying legs. Branchiæ as two or three pairs of vesicles, borne on the thorax.* The *Læmodipoda* are small Crustaceans, which are distinguished amongst the *Edriophthalmata* by the rudimentary condition of the abdomen. The first thoracic segment is amalgamated with the head, and the limbs of this segment appear to be inserted beneath the head, or, as it were, beneath the throat (fig. 153); hence the name given to the order. The respiratory organs are in the form of two or three pairs of membranous vesicles attached to the segments of the thorax, or to the bases of the legs. The last pair of feet are either inserted at the end of the last somite, or are followed by not more than one or two small segments. There are four setaceous antennæ, and the mandibles are without palps. The body is generally linear, of eight or nine joints, but is sometimes oval. The feet are hooked. The *Læmodipoda* are all marine, and one section of the order comprises parasitic Crustaceans, of which the Whale-louse (*Cyamus ceti*) is the most familiar. The entire order is now generally regarded as being merely a section of the *Amphipoda*.

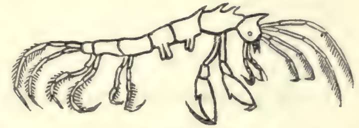

Fig. 153.—Læmodipoda. *Caprella phasma.*

ORDER II. AMPHIPODA.—The members of this order resemble those of the preceding in the nature of *the respiratory organs, which consist of membranous vesicles attached to the bases of the thoracic limbs. The first thoracic segment, however, is distinct from the head, and the abdomen is well developed, and is composed of seven segments. There are seven pairs of thoracic limbs, directed partly forwards and partly backwards,* the name of the order being derived from this circumstance. As in the *Læmodipoda*, the heart has the form of a long tube extending through the six segments following the head, and having the blood admitted to its interior by three pairs of valvular fissures. The three posterior pairs of abdominal limbs are bent backwards, and form, with the telson, a natatory or saltatorial tail. The young Amphipod acquires its full number of segments and limbs before its liberation from the egg; and, as a rule, the young undergo little or no metamorphosis in reaching maturity.

All the *Amphipoda* are small, the "Sand-hopper" (*Talitrus locusta*, fig. 154) and the "fresh-water Shrimp" (*Gammarus pulex*) being two of the commonest forms. The Sand-hoppers and Gammari swim on their side when in the water, and the former leap with great activity on land.

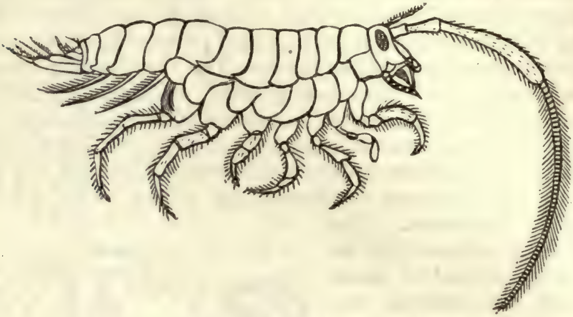

Fig. 154.—Amphipoda. The Sand-hopper, *Talitrus locusta*, enlarged.

ORDER III. ISOPODA.—In this order *the head is always distinct from the segment bearing the first pair of feet. The respiratory organs are not thoracic*, as in the two preceding orders, *but are attached to the inferior surface of the abdomen, and consist of branchiæ, which in the terrestrial species are protected by plates which fold over them. The thorax is composed of seven segments, bearing seven pairs of limbs*, which, in the females, have marginal plates, attached to their bases, and serving to protect the ova. The number of segments in the abdomen varies, but is never more than seven. The abdominal segments are coalescent, and form a broad caudal shield, beneath which the branchiæ are carried. The eyes are two in number, formed of a collection of simple eyes, or sometimes truly compound. The heart is sometimes an elongated tube, with three pairs of fissures (as in the *Amphipoda*), sometimes short or spherical, removed towards the abdomen, and with more or fewer fissures than the above. The young Isopod is developed within a larval membrane, destitute of appendages. After a time this membrane bursts, and liberates the young, which resembles the adult in most respects, but possesses only six instead of seven pairs of limbs. Of the members of this order, many are aquatic in their habits, and are often parasitic, but others are terrestrial.

By Milne-Edwards the *Isopoda* are divided into three sections, termed respectively, from their habits, the *Natatorial*, *Sedentary*, and *Cursorial Isopods*. In the *Natatorial Isopoda* the extremity of the abdomen and the last pair of abdominal legs are expanded so as to form a swimming-tail. Some of this section are parasitic upon various fishes (*Cymothoa*), whilst others are found in the sea (*Sphæroma*). In the *Sedentary Isopoda* the animals are all parasitic, with short, incurved, hooked feet. This section includes the single family of the *Bopyridæ*, all the species of which live parasitically either in the gill-chambers, or attached to the ventral surface, of certain of the Decapod *Crustacea*, such as the Shrimps, (*Crangones*) and the *Palæmones*.

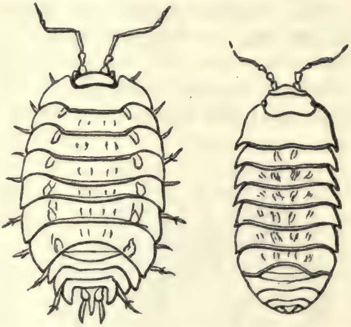

Fig. 155.—Isopoda. Woodlice (*Oniscus*), twice the natural size.

The *Cursorial*, or running *Isopods* mostly live upon the land, and are therefore destitute of swimming-feet. The most familiar examples of this section are the common Wood-lice (*Oniscus*). Here, also, belongs the little *Limnoria terebrans*, so well known for the destruction which it produces by boring into the wood-work of piers and other structures placed in the sea. Other well-known Isopods are the Water-slaters (*Asellus*) of fresh waters, the Rock-slaters (*Ligia*) of almost all coasts, the Box-slaters (*Idothea*), the Shield-slaters (*Cassidina*), and the Cheliferous Slaters (*Tanais*). These last are remarkable as being the only Isopods in which there is a carapace. The lateral parts of the carapace, also, are highly vascular, and respiration is effected by these, and not by the abdominal feet.

Many Isopods undergo an extensive metamorphosis. "In some Fish-lice (*Cymothoa*) the young are lively swimmers, and the adults are stiff, heavy, stupid fellows, whose short clinging feet are capable of little movement." In the *Bopyridæ* the adult females are usually blind, the antennæ are rudimentary, and the abdominal appendages from natatory become respiratory organs. The males, on the other hand, are dwarfed, and sometimes lose all the abdominal appendages and all traces of segmentation; until we get forms which, like *Cryptoniscus planarioides*, "would be regarded as a Flat-worm rather than an Isopod, if its eggs and young did not betray its Crustacean nature" (Fritz Müller).

DIVISION B. PODOPHTHALMATA.—The members of this division have compound eyes supported upon movable stalks or peduncles, and the body is always protected by a cephalo-thoracic carapace. Most of the *Podophthalma* pass through Zoea-stages in their development. It comprises the two orders *Stomapoda* and *Decapoda*, of which the latter includes all the highest and most familiar examples of the class *Crustacea*.

ORDER I. STOMAPODA.—In this order there are generally *from six to eight pairs of legs, and the branchiæ, when present, are not enclosed in a cavity beneath the thorax, but are either suspended beneath the abdomen, or, more rarely, are attached to the thoracic legs.* The shell, also, is thin, and often membranous. From all the preceding orders the *Stomapoda* are, of course, distinguished by the possession of pedunculate eyes. The development of the *Stomapoda* would appear to be by means of "Zoeæ."

All the Stomapoda are marine, with the single exception of the *Mysis relicta* of the great lakes of Sweden and North America; and the Locust Shrimp (*Squilla mantis*) may be taken as a good example of the order. In this Crustacean (fig. 156) the carapace is small, and does not cover the posterior half of the thorax. The eyes and antennæ are attached to a somite which is not soldered to the cephalothorax. Several of the anterior appendages are developed into powerfully prehensile and hooked feet. The branchiæ are attached to the first five pairs of abdominal feet. The three posterior thoracic and the abdominal appendages are in the form of "swimmerets," and the tail is expanded into a powerful fin. Besides the Locust Shrimps, the order includes the Glass Shrimps (*Erichthys*) and their allies, and the Opossum Shrimps (*Mysis*).

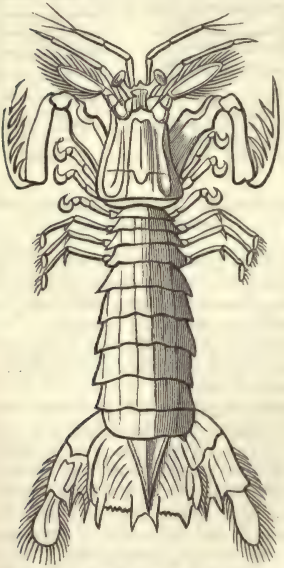

Fig. 156.—*Squilla mantis*, the Locust Shrimp.

ORDER II. DECAPODA.—The members of this order are the most highly organised of all the *Crustacea*, as well as being those which are most familiarly known, the Lobsters, Crabs, Shrimps, &c., being comprised under this head. For the most part they are aquatic in their habits, and they are usually protected by strong resisting shells. There is always a complicated set of "gnathites," or appendages modified for masticatory purposes, surrounding the mouth. *The ambulatory feet are made up of five pairs of legs* (hence the name of the order); *the first pair—and often some other pairs behind this—being "che-*

late," or having their extremities developed into nipping-claws. The branchiæ are pyramidal, and are contained in cavities at the side of the thorax. The carapace is large, covering the head and thorax, and the anterior part of the abdomen. The heart of the *Decapoda* is in the form of a more or less quadrate sac, furnished with three pairs of valvular openings. As regards the development of the Decapods enormous differences obtain, even amongst forms very closely allied to one another.

The *Decapoda* are divided into three tribes, termed respectively the *Macrura*, *Anomura*, and *Brachyura*, and characterised by the nature of the abdomen.

TRIBE A. MACRURA.—The "long-tailed" Decapods included in this tribe are distinguished by the possession of a well-developed abdomen, often longer than the cephalothorax, the posterior extremity of which forms a powerful natatory organ or caudal fin. As regards the development of the *Macrura*, most appear at first in the form of "Zoeæ;"* but there is little metamorphosis in the common Lobster, and there is said to be none in the Cray-fish (*Astacus fluviatilis*). Fritz Müller, again, has shown that the primitive form of one of the Shrimps (*Peneus*) is that of a "Nauplius." Lastly, the young of the Spiny Lobster (*Palinurus vulgaris*) are transparent *Phyllosomæ*, resembling Stomapods in appearance. This section comprises the Lobster, Cray-fish, Shrimp, Prawn, &c., of which the Lobster may be taken as the type.

In the Lobster (figs. 136, 137), as also in the Cray-fish (fig. 157), the somites of the head and thorax are amalgamated into a single mass, the "cephalothorax," covered by a carapace or shield, which is developed from "the lateral or epimeral elements of the fourth cephalic ring, which meet along the back, and give way preparatory to the moult. The tergal elements of the thoracic rings are not developed in either Crabs or Lobsters; when these rings are exposed by lifting up the cephalothoracic shield, the epimeral parts alone are seen, converging obliquely towards one another, but not joined at their apices" (Owen).

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* The young Decapod, in most cases, leaves the egg in a larval form so different to the adult that it was originally described as a distinct animal under the name of *Zoea*. In this stage (fig. 160) the thoracic segments with the five pairs of legs proper to the adult are either wanting or are quite rudimentary. The abdomen and tail are without appendages, and the latter is composed of a single piece. The foot-jaws are in the form of natatory forked feet, and the mandible has no palp. Lastly, there are no branchiæ, and respiration is carried on by the lateral parts of the carapace. The "Zoea" is separated from the "Nauplius" by having a segmented body, large paired eyes (sometimes with a median eye), and a carapace. The form proper to the adult is not attained until after several moults, constituting a genuine metamorphosis, though one which is effected by very gradual stages.

The first segment of the head bears the compound eyes, which are supported upon long and movable eye-stalks or peduncles. Behind these come two pairs of jointed tactile organs, the larger called the "great antennæ," the smaller the "antennules." The mouth is situated on the under surface of the front of the head, and is provided from before backwards with an upper lip ("labrum"), two "mandibles," two pairs of "maxillæ," three pairs of "maxillipedes" or "foot-jaws," and a bifid lower lip, or "metastoma" (fig. 158). The five remaining segments of the thorax carry the five pairs of ambulatory legs, of which the first constitute the great claws, or "chelæ;" the next two pairs are also chelate, though much smaller; and the last two pairs are terminated by simply pointed extremities.

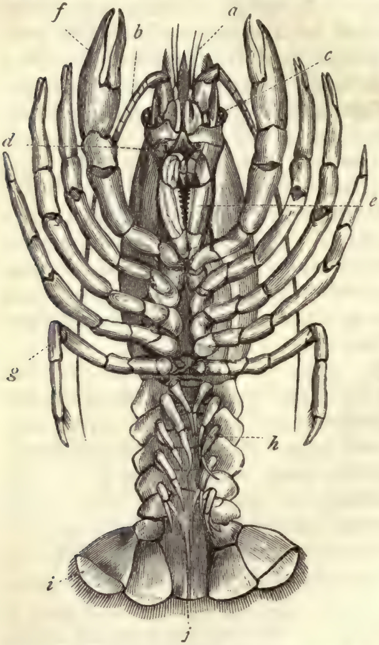

Fig. 157.—The common Cray-fish (*Astacus fluviatilis*), viewed from below. *a* Antennules; *b* Large antennæ; *c* Eyes; *d* Opening of auditory sac; *e* Last pair of foot-jaws; *f* One of the great chelæ; *g* Fifth thoracic limb; *h* Swimmerets; *i* The last pair of swimmerets; *j* The opening of the anus below the telson.

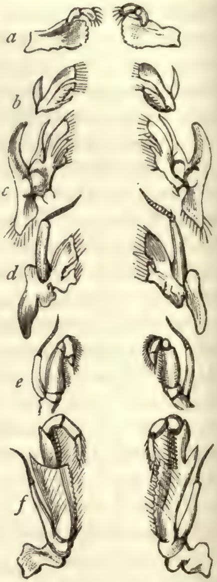

Fig. 158.—Gnathites of the Cray-fish (*Astacus fluviatilis*). *a* Mandibles; *b* Maxillæ; *c* Second pair of maxillæ; *d* First pair of foot-jaws; *e* Second pair of foot-jaws; *f* Third pair of foot-jaws.

The segments of the abdomen carry each a pair of natatory limbs, or "swimmerets," the last pair being greatly expanded, and constituting, with the "telson," a powerful caudal fin. Most posteriorly of all is the post-anal plate, or "telson," which may be looked upon either as an azygous appendage, or as a terminal segment which has no lateral appendages.

The mouth leads by a short œsophagus into a globose stomach, in the cardiac portion of which is a calcareous apparatus, for triturating the food, which is commonly called the "lady in the lobster." The intestine is continued backwards from the stomach without convolutions, and the anal aperture is situated just in front of the telson. There is also a well-developed liver, consisting of two lobes which open by separate ducts into the intestine.

The heart is situated dorsally, and consists of a single polygonal contractile sac, which opens by valvular apertures into a surrounding venous sinus, inappropriately called the "pericardium." The heart is filled with oxygenated blood derived from the gills, and propels the aerated blood through every part of the body. The gills (fig. 137, 3, *g*) are pyramidal bodies attached to the bases of the legs, and protected by the sides of the carapace. They consist each of a central stem supporting numerous laminæ, and they are richly supplied with blood, but are not ciliated. The water which occupies the gill-chambers is renovated partly by the movements of the legs, and partly by the expanded epipodite of the second pair of maxillæ, which constantly spoons out the water from the front of the branchial chamber, and thus causes an entry of fresh water by the posterior aperture of the cavity.

The nervous system is of the normal "homogangliate" type, consisting of a longitudinal series of ganglia of different sizes, united by commissural cords, and placed along the ventral surface of the body. The organs of sense consist of the two compound eyes, the two pairs of antennæ, and two auditory sacs.

The sexes are invariably distinct, and the generative products are conveyed to the exterior by efferent ducts, which open at the base of one of the pairs of thoracic legs. The ovum is "meroblastic," a portion only of the vitellus undergoing segmentation. The neural side of the body—that is to say, the ventral surface—appears on the surface of the ovum, so that the embryo is built up from below, and the umbilicus is situated posteriorly.

Tribe B. Anomura.—The Decapods which belong to this tribe are distinguished by the condition of the abdomen, which is neither so well developed as in the *Macrura*, nor so rudimentary as in Crabs. Further, the abdomen does not terminate posteriorly in a caudal fin, as in the Lobster. The development in the *Anomura* appears invariably to take place through Zoea-forms.

The entire group of the *Anomura* must be regarded as an artificial assemblage, composed of modified forms of both the *Macrura* and the *Brachyura.*

The most familiar of the *Anomura* are the Hermit-crabs (*Paguridæ*). In the common Hermit-crab (*Pagurus Bernhardus*) the abdomen is quite soft, and is merely enclosed in a membrane, so that the animal is compelled to protect itself by adopting the empty shell of some Mollusc, such as the common Whelk, which it changes at will when too small. The Hermit is provided with a terminal caudal sucker, and with two or three pairs of rudimentary feet developed upon the abdomen, by means of which he retains his position within his borrowed dwelling. The abdominal appendages, however, are mostly unsymmetrical. The carapace is not strong, but the claws are

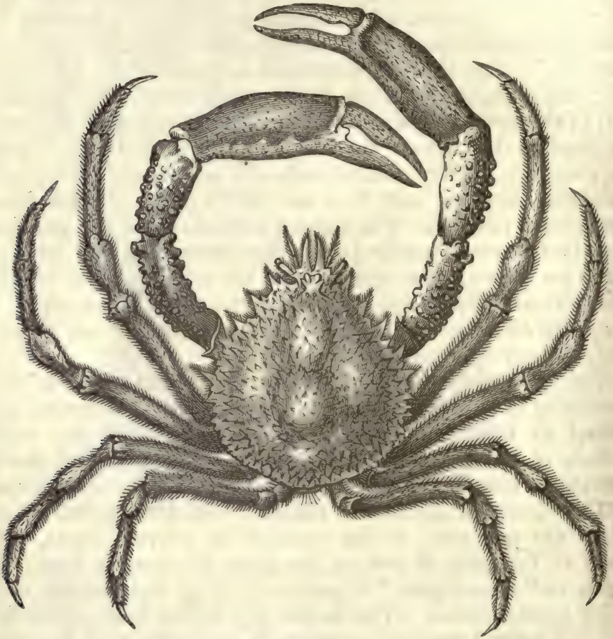

Fig. 159.—Brachyura. The Spiny Spider-crab (*Maia squinado*).

well developed, one being always larger than the other. Other forms of the *Anomura* are the Sponge-crabs (*Dromia*), the Crab-lobsters (*Porcellanæ*), and the Tree-crabs (*Birgus*).

TRIBE C. BRACHYURA.—The "short-tailed" Decapods, or Crabs, are distinguished from the two preceding tribes by the rudimentary condition of the abdomen, which is very short, and is tucked up beneath the cephalothorax, the latter being disproportionately large. The extremity of the abdomen is not provided with any appendage, and it is merely employed by the female to carry the ova. The Crabs (fig. 159) are mostly furnished with ambulatory limbs, and are rarely formed for swimming, most of them being littoral in their habits, and some even living inland.

In all the essential points of their anatomy the Crabs do not differ from the Lobster and the other *Macrura;* but they are decidedly higher in their organisation. This is especially seen in the disposition of the nervous system, the ventral ganglia in the Crab being concentrated into a single large ganglion, from which nervous filaments are sent to all parts of the body. In the Land-crabs (*Gecarcinus*) respiration is by branchiæ, but there is almost always an aperture behind the carapace for the admission of air. They are distributed over the warm countries of the Old and New Worlds, as well as Australia. They are essentially terrestrial in their habits, and migrate in large bodies to the sea, in order to lay their eggs. Besides the true *Gecarcini*, members of other very different families live more or less constantly on dry land, and have air admitted directly into the branchial chamber. Amongst these are the Calling crabs (*Gelasimus*) and the Sand-crabs (*Ocypoda*).

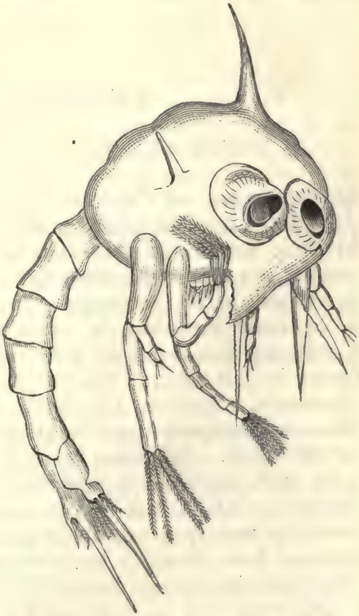

Fig. 160.—Zoea of the Spiny Spider-Crab (*Maia squinado*), enlarged.

Reproduction in the Crabs is the same as in the *Macrura*, but the larva is exceedingly unlike the adult, and approximates closely to the type of the *Macrura*, another proof that the *Brachyura* stand higher in the Crustacean scale. The larval Crab was originally described as a distinct animal, under the name of *Zoea* (fig. 160), presenting in this condition a long and well-developed abdomen. It is only after several successive moults that the young Crab assumes its characteristic Brachyurous form, and acquires by gradual changes the features which distinguish the adult. The *Zoeæ* of the Crabs are usually distinguished by the possession of long spines developed from the carapace. When first liberated from the egg, the Zoea is enveloped in a larval skin or membrane, which is shed in a few hours. Among the Land-crabs, there is no metamorphosis in *Gecarcinus;* but in some of the *Gecarcinidæ* the young are *Zoeæ*.

CHAPTER XXXIV.

DISTRIBUTION OF THE CRUSTACEA.

Distribution of Crustacea in Space.—The *Crustacea* are distributed over the whole globe, some forms being terrestrial in their habits, but the majority inhabiting the sea or fresh water. As a rule, the development of the Crustacean fauna is in proportion to the temperature, the higher and larger forms being most abundant in warm regions. The groups of the *Cirripedia*, *Rhizocephala*, *Xiphosura*, and *Læmodipoda*, are only found in salt water. On the other hand, the *Ichthyophthira*, *Ostracoda*, *Copepoda*, *Phyllopoda*, *Eurypterida* (?), *Amphipoda*, *Stomapoda*, *Isopoda*, and *Decapoda*, are found both in fresh and in salt water. Of these, however, the Phyllopods are principally fresh-water forms, and the Stomapods and Decapods are essentially inhabitants of the sea; whilst the Eurypterids are certainly mainly a salt-water group, though some forms may perhaps have lived in fresh water as well. The *Isopoda* and *Decapoda* also include terrestrial forms.

Distribution of Crustacea in Time.—As regards the general distribution of the *Crustacea* in time, remains of the class are comparatively abundant in all formations except the very oldest; as might have been expected from the generally chitinous or sub-calcareous nature of their integuments and their aquatic habits. Owing also to their habit of periodically casting their shell, a single individual may leave repeated traces of himself, and the number of fossils may considerably exceed that of the individuals which actually underwent fossilisation. The Crustaceans appear to have commenced their existence in the Cambrian period, remains of members of this class being tolerably abundant in the higher portion of this formation. The Palæozoic formations, taken as a whole, are characterised by the predominance of the orders *Trilobita*, *Eurypterida*, *Ostracoda*, and *Phyllopoda*, of which the two former are exclusively confined to this period. All the other orders of *Crustacea* which have left any traces of their past existence at all, appear to have come into existence before the close of the Palæozoic period. Upon the whole, however, there has been a marked progression in proceeding from the older formations to the present day. The Trilobites and Eurypterids of the older Palæozoic rocks, though highly organised so far as their type is concerned, are in many respects inferior to later forms, whilst they present some striking points of resemblance to the larval forms of the higher groups. The great group of the Stalk-eyed Crustaceans—undoubtedly the highest of the entire class—is not represented at all till we reach the Devonian rocks; and it is not till we come into the Secondary period that we find any great development of this group, whilst its abundance increases to a marked extent in the Tertiary period, and it attains its maximum at the present day. Similarly, of the two orders of the *Merostomata*, the *Eurypterida* are confined to the earlier portion of the Palæozoic period, whilst the more highly organised and less larval King-crabs (*Xiphosura*) hardly made their appearance till the Eurypterids had disappeared, at the close of the Carboniferous period.

1. *Cirripedia.*—The Cirripedes are hardly known as Palæozoic fossils, but valves of a singular member of this order (*Turrilepas*) have been found in the Silurian rocks. With few exceptions, the Cirripedes are entirely confined in past time to the Secondary and Tertiary epochs. The *Balanidæ* are the most common, commencing, with the doubtful exception of a Liassic form, in the Chalk, and attaining their maximum in recent seas. The *Verrucidæ* commence in the Chalk, and the *Lepadidæ*, with one or two exceptions, begin in the Jurassic rocks, and attain their maximum of development in the Cretaceous epoch. The Upper Silurian genus *Turrilepas*, above mentioned, is also referable to the Lepadoids.

2. *Ostracoda.*—Small Ostracode *Crustacea* are extremely abundant as fossils in many formations, and extend from the Cambrian period up to the present day.

3. *Phyllopoda.*—Remains of Crustaceans supposed to belong to this order are found in the Palæozoic rocks. *Hymenocaris* is found in the Upper Cambrian, *Caryocaris* in the Lower Silurian, *Ceratiocaris* in the

Upper Silurian, and *Dithyrocaris* in the Carboniferous Limestone. All these forms, with other similar ones, are believed to be most closely allied to the recent *Apus* and *Nebalia*. The genus *Estheria*, represented by many forms from the Devonian period to the present day, is also to be referred here.

4. *Trilobita.*—The Trilobites are exclusively Palæozoic fossils. In the Upper Cambrian rocks—the so-called "primordial zone"—there occurs a singular group of Trilobites—the so-called primordial Trilobites—distinguished by the possession of many larval characters. In the Lower and Upper Silurian rocks the Trilobites attain their maximum of development. They are still well represented in the Devonian rocks; but they die out completely before the close of the Carboniferous epoch, being represented in the Mountain Limestone by four genera only (*Phillipsia*, *Brachymetopus*, *Proetus*, and *Griffithides*).

5. *Eurypterida.*—These, like the last, are entirely Palæozoic, attaining their maximum in the Upper Silurian and Devonian formations, and dying out in the Carboniferous rocks. *Pterygotus*, *Eurypterus*, and *Slimonia* are the most characteristic genera.

6. *Xiphosura.*—The genus *Limulus* commenced, as far as is yet known, in the Permian period, and has survived up to the present day. Its first appearance, therefore, was just at the close of the Palæozoic epoch. Of the remaining genera, which constitute with *Limulus* this sub-order, *Belinurus*, *Euproöps*, and *Prestwichia*, are Palæozoic, and are not known to occur out of the Carboniferous rocks. The genus *Neolimulus* is Upper Silurian.

7. *Amphipoda.*—The oldest known Amphipod is the *Necrogammarus* of the Upper Silurian.

8. *Isopoda.*—The earliest known Isopod is the *Præarcturus* of the Devonian rocks.

9. *Stomapoda.*—This order is doubtfully represented in the Carboniferous rocks by the genus *Palæocaris*, and by some allied types.

10. *Decapoda.*—The Macrurous Decapods commence their existence in the Carboniferous period, or perhaps in the Devonian, with a few Prawn-like forms; and the *Brachyura* seem to have existed at the same period. The *Decapoda* are, however, well represented, in all their three tribes, in the Secondary and Tertiary epochs, attaining their maximum at the present day. The London Clay (Eocene) is especially rich in the remains of *Macrura* and *Brachyura*.

CHAPTER XXXV.

ARACHNIDA.

CLASS II. ARACHNIDA.—The *Arachnida*—including the Spiders, Scorpions, Mites, &c.—possess almost all the essential characters of the *Crustacea*, to which they are very closely allied. Thus, the body is divided into a variable number of somites, some of which are always provided with articulated appendages. A pair of ganglia is primitively developed in each somite, and the neural system is placed ventrally. The heart, when present, is always situated on the opposite side of the alimentary canal to the chain of ganglia. The respiratory organs, however, whenever these are differentiated, are never in the form of branchiæ as in the *Crustacea*, but are in the form either of pulmonary vesicles or sacs, or of ramified tubes, formed by an involution of the integument, and fitted for breathing air directly. Further, there are never "more than four pairs of locomotive limbs, and the somites of the abdomen, even when these are well developed, are never provided with limbs;" the reverse being the case amongst the *Crustacea*. Lastly, "in the higher *Arachnida*, as in the higher *Crustacea*, the body is composed of twenty somites, six of which are allotted to the head; but in the former class, one of the two normal pairs of antennæ is never developed, and the eyes are always sessile; while, in the higher *Crustacea*, the eyes are mounted upon movable peduncles, and both pairs of antennæ are developed" (Huxley).

The head of the *Arachnida* is always amalgamated with the thorax, to form a "cephalothorax;" the integument is usually chitinous, and the locomotive limbs are mostly similar in form to those of insects, and are usually terminated by two hooks.

In many of the *Arachnida* the integument remains soft over the entire body; in others, as in the majority of Spiders, the abdomen remains soft and flexible, whilst the cephalothorax is more or less hard and chitinous; in the Scorpions, again, the integument over the whole body forms a strong chitinous shell. The cephalothorax may be segmented (*Solpugidæ*); and the abdomen may or may not be segmented. Though four pairs of legs are present, the first is certainly homologous with the labial palpi of the *Insecta*.

The typical somite of the *Arachnida* is constituted upon exactly the same plan as that of the *Crustacea*, consisting essentially of a dorsal and ventral arc; the former composed of a central piece, or "tergum," and of two lateral pieces, or "epimera;" whilst the latter is made up of a median "sternum" and of two lateral "episterna."

As regards the composition of the cephalothorax of Spiders, "the tergal elements of the coalesced segments are wanting, and the back of the thorax is protected by the elongation, convergence, and central confluence of the epimeral pieces; the sternal elements have coalesced into the broad plate in the centre of the origins of the ambulatory legs, from which it is separated by the episternal elements. . . . The non-development of the tergal elements explains the absence of wings" (Owen).

The mouth is situated, in all the *Arachnida*, in the anterior segment of the body, and is surrounded by suctorial or masticatory appendages. In the higher *Arachnida*, the mouth is provided from before backwards with the following appendages (figs. 161, 162): 1. A pair of "falces," or "mandibles," used for prehension; 2. A pair of "maxillæ," each of which is provided with a long jointed appendage, the "maxillary palp;" 3. A lower lip, or "labium." In the Scorpion, an upper lip, or "labrum," is also present.*

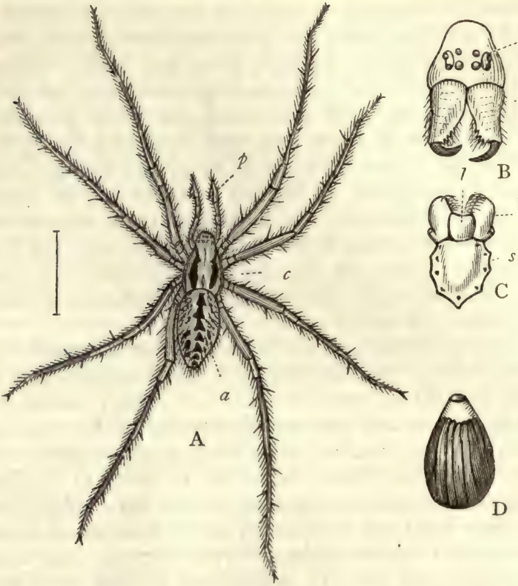

Fig. 161.—A, The male of the common House-Spider (*Tegenaria civilis*), considerably magnified: *c* Front portion of the body, consisting of the amalgamated head and thorax; *p* Maxillary palpi; *a* Abdomen. B, Front portion of the head of the same, showing the eight eyes (*f*), and the mandibles (*n*). C, Under side of the head and trunk, showing the true jaws (*m*), the lower lip (*l*), and the horny plate to which the legs are attached. D, Diagram of one of the air-chambers or breathing-organs. (Figs. A, B, and C are after Blackwall.)

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* The nomenclature ordinarily applied to the parts of the mouth in the *Arachnida* is a misleading one, so far as the homologies of this class with the *Insecta* are concerned. Thus the so-called "mandibles" are really the *antennæ;* the "mandibles" themselves are absent, but the "chelæ" of the Scorpions may really represent the "*mandibular palpi;*" whilst the first pair of *legs* really correspond with the "*labial palpi,*" and the second pair of legs may possibly be a modification of a second pair of palps.

In the Spiders (fig. 162, 4) each falx or mandible terminates in a sharp movable hook, which possesses an aperture at its extremity communicating by a canal with a gland, which is placed in the preceding joint of the mandible, and secretes a poisonous fluid. The maxillary palps in the Spiders are long, jointed appendages, terminated in the females by pointed claws, but frequently swollen, and carrying a special sexual apparatus in the males.

In the Scorpions (fig. 162, 1) the mandibles are short and terminate in strong pincers, or "cheliceræ." The maxillary palpi are also greatly developed, and constitute powerful grasping claws, or "chelæ." In the genus *Galeodes*, the mandibles, like those of the Scorpion, constitute "cheliceræ," though comparatively much larger and longer; but the maxillary palps are not developed into "chelæ."

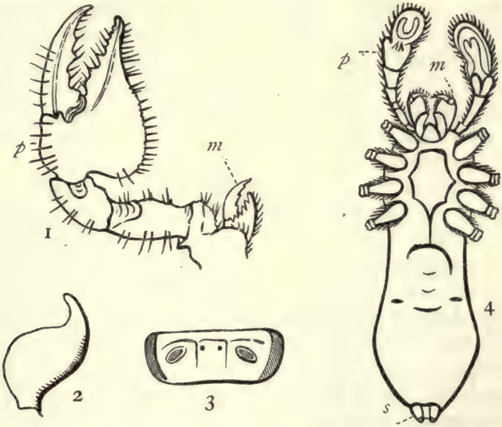


Fig. 162. — Morphology of Arachnida. 1. Organs of the mouth in the Scorpion, on one side: *m* Mandibles (antennæ) converted into chelæ, and called the chelicerae; *p* Maxillary palpi greatly developed, and forming strong chelæ. 2. Telson of the Scorpion. 3. One of the abdominal segments of the Scorpion, showing the "stigmata," or apertures of the pulmonary sacs. 4. *Tegenaria civilis*, the common Spider (male), viewed from below: *s* Spinnerets; *m* Mandibles with their perforated hooks—below the mandibles are the maxillæ, and between the bases of these is the labium; *p* The maxillary palpi with their enlarged tumid extremities.

With regard to antennæ, these organs, *as such*, do not exist in the *Arachnida*. It is generally believed, however, that the *mandibles* of the *Arachnida* are truly homologues, not of the parts which bear the same name in the other *Arthropoda*, but of the *antennæ;* and the name of "falces" is thus best applied to them. The antennæ, therefore, of the Spiders are converted into prehensile and offensive weapons; whilst in the Scorpions, as in the King-crabs, they are developed into nipping-claws, or chelæ.

In the lower *Arachnida*, the organs of the mouth, though essentially the same as in the higher forms, are often enveloped in a sheath, formed by the labium and maxillæ, whilst the mandibles are often joined together so as to constitute a species of lancet.

The mouth conducts by an œsophagus, sometimes by the intervention of a pharynx, to the stomach, which often carries longer or shorter cæca appended to it. The intestinal canal is short and straight, no convolutions intervening between the mouth and the anus. The terminal portion of the intestine is generally dilated into a cloaca, into which open, as a rule, branched or tortuous tubes, supposed to have a renal function, and to correspond with the "Malpighian vessels" of Insects. Salivary glands are generally present, and there is usually a well-developed liver.

The circulation in the *Arachnida* is maintained by a dorsal heart, which is situated above the alimentary canal, and is wanting in the lower forms. Usually the heart is greatly elongated, and resembles the "dorsal vessel" of the *Insecta*. In the lower *Arachnida*, however, there is no central organ of the circulation, and there are no differentiated blood-vessels. All the *Arachnida*, except some of the lowest, breathe the air directly, and the respiratory function is performed by the general surface of the body (as in the lowest members of the class), or by ramified air-tubes, termed "tracheæ," or by distinct pulmonary chambers or sacs; or, lastly, by a combination of tracheæ and pulmonary vesicles. The "tracheæ" consist of ramified or fasciculated tubes, opening upon the surface of the body by distinct apertures, called "stigmata." The walls of the tube are generally prevented from collapsing by means of a chitinous fibre or filament, which is coiled up into a spiral, and is situated beneath their epithelial lining. The pulmonary sacs, or "tracheal lungs," are simply involutions of the integument, abundantly supplied with blood; the vascular surface thus formed being increased in area by the development of a number of close-set membranous lamellæ, or vascular plates, which project into the interior of the cavity. Like the tracheæ, the pulmonary sacs communicate with the exterior by minute apertures, or "stigmata" (fig. 162, 3), and they are to be regarded as being simply greatly expanded tracheæ.

The nervous system is of the normal articulate type, but is often much concentrated. Typically there is a cephalic or "cerebral" ganglion, a large thoracic ganglion, and often small abdominal ganglia. In some of the lower forms the articulate type of nervous system is lost, and there is merely a ganglionic mass situated in the abdomen. In none of the *Arachnida* are compound eyes present, and in none are the eyes supported upon foot-stalks. The organs of vision, when present, are in the form of from two to eight or more simple eyes, or "ocelli."

In all the *Arachnida*, with the exception of the *Tardigrada*, the sexes are distinct. The great majority of the *Arachnida* are oviparous, and in most cases the larvæ are like the adult in all except in size. In some cases, however (*Acarina*), the larvæ have only six legs, and do not attain the proper four pairs of legs until after some moults.

CHAPTER XXXVI.

DIVISIONS OF THE ARACHNIDA.

THE class of the *Arachnida* may be divided into the following orders:—

ORDER I. PODOSOMATA (*Pantopoda*).—*Respiration effected by the general surface of the body; limbs four pairs in number, elongated; abdomen rudimentary, unsegmented; sexes distinct.*

The members of this order, sometimes called "Sea-spiders," have been placed alternately amongst the *Arachnida* and the *Crustacea*, their true position being rendered doubtful by the fact that, though marine in their habits, they possess no differentiated respiratory organs. They possess, however, no more than four pairs of legs, and would therefore appear to be properly referable to the *Arachnida*. According to Dr Dohrn, however, the embryo is naupliiform, and this would support a reference of the order to the *Crustacea*. The commoner forms of the *Podosomata* (such as *Nymphon* and *Pycnogonum*) may be found on the sea-coast at low water, crawling about amongst marine plants or hiding beneath stones. Some species of the latter genus are parasitic upon fishes and other marine animals, but the common British species (*P. littorale*) is free when adult, and does not appear to be parasitic at any stage of its existence (fig. 164, *a*). The legs consist of four pairs, sometimes greatly exceeding the body in length, and containing cæcal prolongations of the digestive cavity for a portion of their length. The mouth is sometimes provided with a pair of "cheliceræ," or chelate mandibles, and with two well-developed maxillary palpi, behind which in the female is a pair of false legs which carry the ova. The abdomen is rudimentary; but the cephalothorax is segmented. Though there are no respiratory organs, there is a distinct heart. The sexes are in different individuals, and the larvæ have at first only two pairs of legs.

ORDER II. ACARINA or MONOMEROSOMATA. — The members of this order possess *an unsegmented abdomen which is fused with the cephalothorax into a single mass. Respiration is effected by tracheæ, or by the integument.* Most of the *Acarina* are parasitic, and the most familiar are the Mites and Ticks.

Family 1. *Pentastomida* (*Linguatulinæ*).—The members of this family are worm-like parasites, which in their adult state are found in the interior of the frontal sinuses, the nose, or the lungs of the Dog, and of other Vertebrate animals. When fully grown (fig. 163) they are completely vermiform, with a soft annulated integument, and possessing no external organs except two pairs of retractile hooks, representing limbs, placed near the mouth. The adult thus presents an external resemblance to the *Tæniæ*, from which, however, they are separated by the details of their internal organisation. There are no differentiated organs of respiration or circulation, but the sexes are distinct. The larvæ (fig. 163, B) are found encysted in the liver or other internal organs of various Vertebrates (including man), and possess two pairs of articulated limbs.

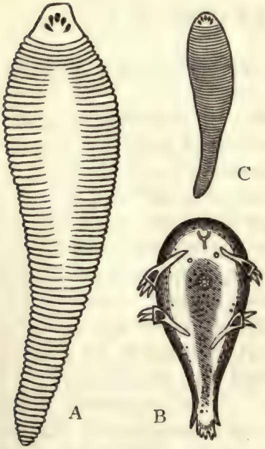


Fig. 163.—A, *Pentastoma tænioides*, female, of the natural size; C, Male of the same, of the natural size; B, Larva of the same, greatly enlarged, showing the two pairs of articulated limbs. (After Spencer Cobbold and Leuckart.)

Family 2. *Tardigrada* (*Macrobiotidæ* or *Arctisca*).—This family comprises the so-called "Sloth" or "Bear Animalcules," which are microscopic animals found in damp moss and in the gutters of houses (fig. 165, B). In form, the body is somewhat vermiform, with four pairs of rudimentary legs. The mouth is suctorial, with rudimentary jaws or stylets. They exhibit no traces of respiratory or circulatory organs, and, unlike the other Arachnids, they have the sexes united in the same individual.

Family 3. *Acarida.*—This family includes the Mites, Ticks, and Water-mites, some of which are parasitic, whilst others are free, and some are even aquatic in their habits. The mouth is formed for suction, or for biting. There is no definite line of demarcation between the unsegmented abdomen and the cephalothorax.

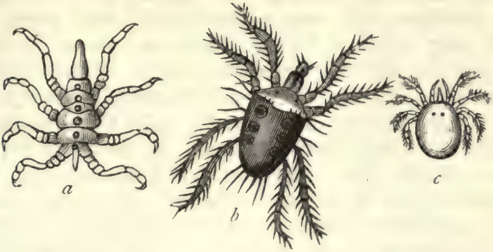


Fig. 164.—Arachnida. *a Pycnogonum littorale ; b Tetranychus telarius*, one of the “Sociable” mites; *c Hydrachna globulus*, one of the “Water-mites.”

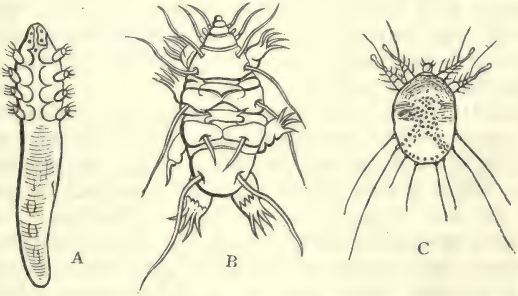


Fig. 165.—A, *Demodex folliculorum*, greatly magnified. B, *Emydium testudo*, one of the *Tardigrada*, greatly magnified. C, *Sarcoptes scabiei*, the Itch-mite, greatly magnified.

In the true *Acari* (fig. 164, *b*), of which the Cheese-mite may be taken as an example, there are four pairs of legs, adapted for walking, and the mouth is provided with distinct mandibles. Besides the Cheese-mite (*A. domesticus*), another well-known species is the *Acarus destructor*, which feeds upon various zoological specimens, and is very annoying to the naturalist. In the *Sarcoptes scabiei*—the cause of the skin-disease known as the “itch”—the two anterior pairs of legs are provided with suckers, and the two posterior are terminated by bristles; the mouth, also, is furnished with bristles (fig. 165, C). In the Ticks (*Ixodes*) the mouth is provided with a beak, or "rostrum," which enables them to pierce the skin and retain their hold firmly. In the *Hydrachnidæ* (fig. 164, *c*), or Water-mites, the head is furnished with two or four ocelli, and there are four pairs of hairy natatory legs. They are parasitic, during at least a portion of their existence, upon Water-beetles and other aquatic insects. They pass through a metamorphosis, the larva being hexapod, or having only three pairs of legs. The Garden-mites (*Trombididæ*) and Spider-mites (*Ganasidæ*) live upon plants; the Wood-mites (*Oribatidæ*) and Harvest-ticks (*Leptidæ*) are to be found amongst moss and herbage, or creeping upon trees or stones; whilst the true Ticks (*Ixodidæ*) attach themselves parasitically by means of their suctorial mouth to the bodies of various Mammals, such as sheep, oxen, dogs, &c. Several Mites (*Thalassarachna*, *Pontarachna*, &c.) have been found to inhabit salt water, and several species of *Trombididæ* live habitually between tide-marks.

Another member of the *Acarina* is the curious little *Demodex folliculorum* (fig. 165, A), which is found in the sebaceous follicles of man, especially in the neighbourhood of the nose. It is probable that very few, if any, individuals are exempt from this harmless parasite.

ORDER III. ADELARTHROSOMATA.—The members of this order, comprising the Harvest-spiders, the Book-scorpions, &c., are distinguished from the preceding by the possession of an *abdomen, which is more or less distinctly segmented, but generally exhibits no line of separation from the cephalothorax, the two regions being of equal breadth and conjoined together. The mouth is furnished with masticatory appendages, and respiration is effected by tracheæ, which open on the lower surface of the body by two or four stigmata.*

Family 1. *Phalangidæ.*—The well-known "Harvest-men" belong to this family. They are characterised by the great length of the legs (fig. 166, B), and by the filiform maxillary palpi, terminated by simple hooks. The abdomen and cephalothorax are of about equal width, but clearly marked off from one another, and the former is segmented. There are two eyes, and the young pass through no metamorphosis. The Harvest-men are active in their habits and live upon animal food.

Family 2. *Pseudoscorpionidæ* (*Cheliferidæ*).—The members of this little group are readily recognised by the fact that the maxillary palpi (fig. 166, A) are of large size, and are converted into nipping-claws or chelæ, thus giving the animal the appearance of a Scorpion in miniature. The abdomen is segmented, but there is no "post-abdomen," as in the true Scorpions. Eyes may be wanting, and the under surface of the abdomen carries a small spinning-organ. The "Book-scorpion" (*Chelifer*) is commonly found in old books and in dark places.

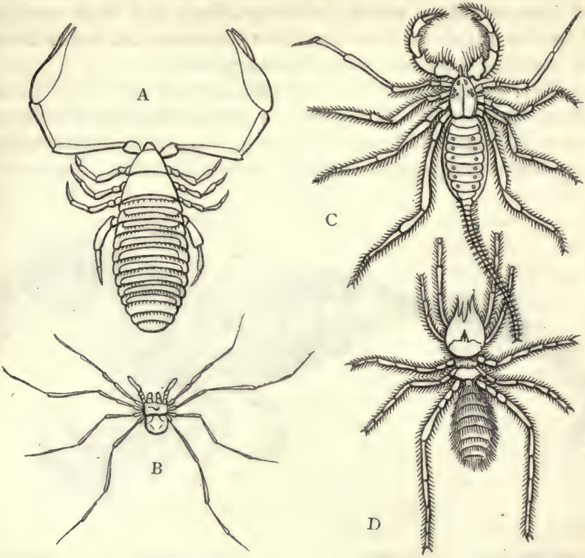


Fig. 166.—A, *Chelifer cancroides*, showing the chelate maxillary palpi, considerably enlarged. B, *Phalangium copticum*, of the natural size. C, *Thelyphonus giganteus*. D, *Galeodes araneoides*, of the natural size.

Family 3. *Solpugidæ*.—In this family (fig. 166, D) the abdomen is not only very distinctly segmented, but is also clearly separated from the cephalothorax, which is likewise segmented. The falces or mandibles are chelate, and of immense size; and the maxillary palpi constitute long feet. The front of the head carries two eyes, and respiration is by tracheæ. *Galeodes* may be considered as the type of the group, all the members of which are tropical or subtropical in their range, and are nocturnal and carnivorous in habit.

ORDER IV. PEDIPALPI.—*Abdomen segmented, with or without a "post-abdomen." Respiration by means of pulmonary sacs.* In this order are the true Scorpions, together with certain other animals which are in some respects intermediate between the Scorpions and the true Spiders. The members of this order are distinguished by the fact that the abdomen in all is distinctly segmented, but is not separated from the cephalothorax by a well-marked constriction. They agree in this character with the *Adelarthrosomata;* hence the two are sometimes united into a single order (*Arthrogastra*), but they are separated by the nature of the respiratory organs, the latter breathing by tracheæ, and not by pulmonary sacs.

Family 1. *Scorpionidæ.*—The Scorpions are amongst the best known of the *Arachnida*, as well as being amongst the largest. They are distinguished by their long, distinctly segmented abdomen, terminating in a hooked claw (figs. 162, 167). This claw, which is really a modified "telson," is the chief offensive weapon of the Scorpion, and is perforated at its point by the duct of a poison-gland which is situated at its base. The abdomen is composed of twelve somites, not counting the telson, of which the last five constitute a true "tail" or "post-abdomen;" but there is no evident line of demarcation between this region and the cephalothorax. The second segment of the abdomen carries below two curious comb-like organs, of uncertain use, but probably connected with reproduction. The thoracic segments carry four pairs of ambulatory feet. There are six, eight, ten, or twelve simple eyes carried on the top of the head. The maxillary palpi are greatly developed, and constitute strong nipping-claws, or "chelæ" (figs. 162, 167). The mandibles (antennæ) also form claws, or "cheliceræ." The respiratory organs are in the form of pulmonary sacs, four on each side, opening upon the under surface of the abdomen by as many stigmata, each of which is surrounded by a raised margin, or "peritrema" (fig. 162, 3).

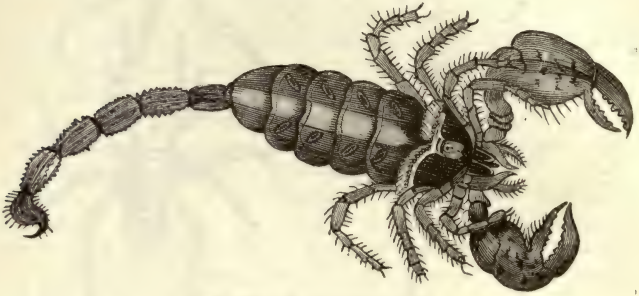


Fig. 167.—Scorpion (reduced).

The Scorpions are mostly inhabitants of warm regions, and their sting, though much exaggerated, is of a very severe nature. They live under stones or in dark crevices, and run swiftly, carrying the tail curved over the back. They feed on insects, which they hold in the chelate palpi, and sting to death. The largest forms, from Central Africa and South America, attain a length of nine or ten inches.

Family 2. *Thelyphonidæ.*—The members of this family in external appearance closely resemble the true Spiders, from which they are separated by the possession of a segmented abdomen, and long spinose palpi, and by the absence of spinnerets. They are distinguished from the *Scorpionidæ* by the amalgamation of the head and thorax into a single mass, which is clearly separated from the abdomen by a constriction, as well as by the fact that the maxillary palpi terminate in movable claws instead of chelæ. Further, the extremity of the abdomen is not furnished with a terminal hook or "sting."

In *Thelyphonus* (fig. 166, C) the abdomen terminates in three post-abdominal segments, to which a long many-jointed caudal appendage is attached; but in *Phrynus* the abdomen ends in a button-like segment. The first pair of legs is the longest (immensely so in *Phrynus*), the falces are not chelate; and the maxillary palpi, though of large size, and sometimes didactyle, do not form true chelæ. The genus *Thelyphonus* is confined to the tropical parts of Asia, America, and Australia, and the genus *Phrynus* is also wholly tropical.

ORDER II. ARANEIDA OR SPHÆROGASTRA.—This order includes the true Spiders, which are characterised *by the amalgamation of the cephalic and thoracic segments into a single mass, and by the generally soft, unsegmented abdomen, attached to the cephalothorax by a constricted portion, or peduncle. Respiration is effected by pulmonary sacs in combination with tracheæ.* (Hence the name *Pulmotrachearia*, sometimes applied to the order.) The number of the pulmonary sacs is smaller in the true Spiders than in the Scorpions, being either two or four, opening by as many stigmata upon the under surface of the abdomen. Usually there are only two pulmonary stigmata, placed just behind the peduncle which unites the cephalothorax with the abdomen, on the lower surface of the latter. In the *Mygalidæ* there are two posterior stigmata, leading into pulmonary sacs; and in other genera there are also two additional stigmata, which, however, open into tracheæ, and not into pulmonary sacs.

The head bears two, four, six, or eight simple eyes; the mandibles are simply hooked, and are perforated by the duct of a gland which secretes a poisonous fluid; and the maxillary palpi are never chelate. The maxillary palpi of the females are almost always leg-like, and are often of the same form in the males. The latter, however, commonly have the ends of the palpi tumid, in which case they appear to be employed for the purpose of conveying the seminal fluid to the female, thus exercising a reproductive function.

Spiders (figs. 162, 168) are all predaceous animals, and many of them possess the power of constructing webs for the capture of their prey or for lining their abodes. For the production of the web, Spiders are furnished with special glands, situated at the extremity of the abdomen. The secretion of these glands is a viscid fluid, which hardens rapidly on exposure to air, and which is cast into its proper, thread-like shape, by being passed through what are called the "spinnerets." These are little conical or cylindrical organs, four or six in number, situated below the extremity of the abdomen, and possibly to be regarded as modified limbs. The excretory ducts of the glands open into the spinnerets, each of which has its apex perforated by a great number of minute tubes, through which the secretion of the glands has to pass before reaching the air. Many spiders, however, do not construct any web, unless it be for their own habitations, but hunt their prey for themselves.

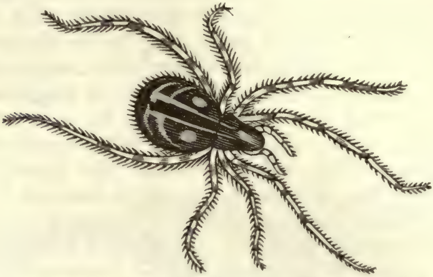


Fig. 168.—Araneida. *Theridion riparium* (female).

The form of the web has been employed as a basis of classification of the Spiders, and amongst its numerous modifications, the following may be specially alluded to: Some forms (such as the common Garden-spiders) construct a web in the form of an incomplete or complete circle, with lines radiating from the centre. These have been termed "*Orbitelariæ.*" Others—the so-called "*Retitelariæ*"—simply spin a thin suspended sheet for their web. Others ("*Tubitelariæ*") construct a silken tube, inserted in any accidental cavity, its mouth being open and guarded by more or fewer threads. Lastly, others ("*Territelariæ*") spin a silken tube in a hole formed by the animal itself, and close its mouth by means of a variously-constructed lid.

The Spiders are oviparous, and the young pass through no metamorphosis; but they cast their skins or moult repeatedly, before they attain the size of the adult. Most Spiders deposit their eggs in silken nests or cocoons, often beautifully constructed, and sometimes carried about by the females. The males are generally smaller than the females, and of rarer occurrence.

DISTRIBUTION OF ARACHNIDA IN TIME.—The *Arachnida* are only very rarely found in a fossil condition. As far as is yet known, both the Scorpions and the true Spiders appear to have their commencement in the Carboniferous epoch, the former being represented by the celebrated *Cyclophthalmus senior* from the coal-measures of Bohemia, and by the *Eoscorpius carbonarius* of the Carboniferous strata of Illinois. Other Carboniferous *Arachnida* have been referred to the genera *Eophrynus*, *Architarbus*, and *Mazonia*. Spiders are also known to occur in the Jurassic rocks (Solenhofen Slates) and in the Tertiary period. The Mites, Harvest-spiders, and Book-scorpions have been detected in amber.

CHAPTER XXXVII.

MYRIAPODA.

CLASS III. MYRIAPODA.—The *Myriapoda* are defined as *articulate animals in which the head is distinct, and the remainder of the body is divided into nearly similar segments, the thorax exhibiting no clear line of demarcation from the abdomen. There is one pair of antennæ, and the number of the legs is always more than eight pairs. Respiration is by tracheæ.*

In this class—comprising the Centipedes (figs. 169, 170) and the Millepedes—the integument is chitinous, the body is divided into a number of somites provided with articulated appendages, and the nervous and circulatory organs are constructed upon a plan similar to what we have seen in *Crustacea* and *Arachnida*. The head is invariably distinct, and there is no marked line of demarcation between the segments of the thorax and those of the abdomen. The body, except in *Pauropus*, always consists of more than twenty somites, and those which correspond to the abdomen in the *Arachnida* and *Insecta* are always provided with locomotive limbs. "The head consists of at least five, and probably of six, coalescent and modified somites; and some of the anterior segments of the body are, in many genera, coalescent, and have their appendages specially modified to subserve prehension" (Huxley). *Pauropus* has only nine pairs of legs; but, with this exception, eleven pairs of legs is the smallest number known in the order.

The respiratory organs, with one exception (*i.e.*, *Pauropus*), agree with those of the *Insecta* and of many of the *Arachnida* in being "tracheæ"—that is to say, tubes, which open upon the surface of the body by minute apertures, or "stigmata," and the walls of which are strengthened by a spirally-coiled filament of chitine. The tracheæ may or may not anastomose with one another as they do in Insects.

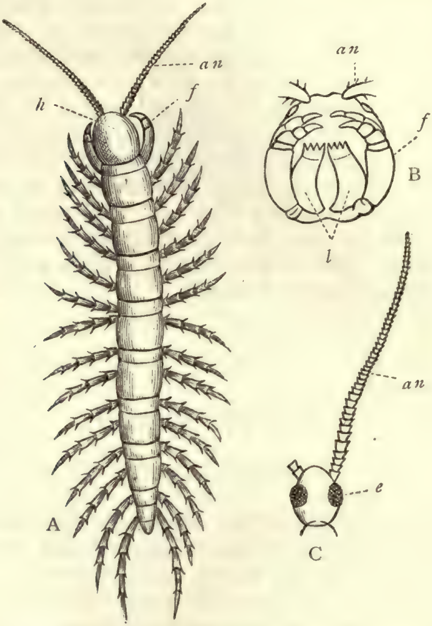


Fig. 169.—A, *Lithobius forficatus*, enlarged and viewed from above: *an* Antennæ; *f* Foot-jaws; *h* Head. B, Head of *Lithobius Leachii*, viewed from below (after Newport): *an* Antennæ; *f* Hooked foot-jaws; *l* Lower lip, composed of two pieces. C, Head of *Lithobius forficatus*, viewed from above (after Gervais): *an* Antenna; *e* Eye.

The somites, with the exception of the head and the last abdominal segment, are usually undistinguishable from one another, and each generally bears a single pair of limbs. In some cases, however, each segment appears to be provided with two pairs of appendages (fig. 171). This is really due to the coalescence of the somites in pairs, each apparent segment being in reality composed of two amalgamated somites. This is shown, not only by the bigeminal limbs, but also by the arrangement of the stigmata, which in the normal forms occur on every alternate ring only, whereas in these aberrant forms they are found upon every ring.

The head always bears a pair of jointed antennæ, resembling those of many Insects, and behind the antennæ there is generally a variable number of simple sessile eyes. In one species (*Scutigera*) compound faceted eyes are present; and in *Pauropus* the antennæ are bifid, and carry many-jointed appendages, thus differing wholly from the antennæ of Insects, and presenting a decided approximation to those of the *Crustacea.*

The young in some cases, on escaping from the egg, possess nearly all the characters of the parents, except that the number of somites, and consequently of limbs, is always less, and increases at every change of skin ("moult" or "ecdysis"). In most cases, however, there is a species of metamorphosis, the embryo being at first either devoid of locomotive appendages, or possessed of no more than three pairs of legs, thus resembling the true hexapod Insects. It is believed, however, that the legs of these hexapod larvæ do not correspond homologically with the three pairs of legs proper to adult Insects. In these cases the number of legs proper to the adult is not obtained until after several moults, the entire process being stated to occupy in some species as much as two years, before maturity is reached.

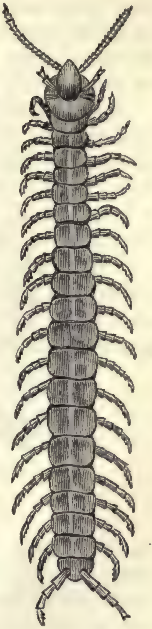


Fig. 170.—Centipede (*Scolopendra*).

The *Myriapoda* are divided into three orders—viz., the *Chilopoda*, the *Chilognatha*, and the *Pauropoda*, to which a fourth, under the name of *Onychophora*, must be provisionally added for the reception of the genus *Peripatus.*

ORDER I. CHILOPODA.—This order comprises the well-known carnivorous Centipedes and their allies, and is characterised by the number of legs being rarely indefinitely great (usually from 15 to 20 pairs), by the composition of the antennæ out of not less than 14 joints (14 to 40 or more), and by the structure of the masticating organs. These consist of a pair of mandibles with small palpi, a labium, and two pairs of "maxillipedes" or foot-jaws, of which the second is hooked, and is perforated for the discharge of a poisonous fluid. There is not more than one pair of legs to each somite, and the last two limbs are often directed backwards in the axis of the body, so as to form a kind of tail. The body in all the *Chilopoda* is flattened, and the generative organs open at the posterior end of the body.

Scolopendra (fig. 170), *Lithobius* (fig. 169), and *Geophilus* are common European genera of this order. The ordinary Centipedes of this country are (unless in exceptional cases) perfectly harmless; but those of tropical regions sometimes attain a length of a foot, or more, and these are capable of inflicting very severe, and even dangerous, bites.

ORDER II. CHILOGNATHA.—This order comprises the vegetable-eating Millepedes (*Iulidæ*), the Galleyworms (*Polydesmus*), and other allied forms. The order is characterised by the great number of legs—each segment, except the five or six anterior ones, bearing two pairs—by the composition of the antennæ out of six or seven joints; and by the structure of the masticating organs, which consist of a pair of mandibles without palps, covered by a lower lip, composed of the confluent maxillæ. The generative apertures are placed in the anterior portion of the body.

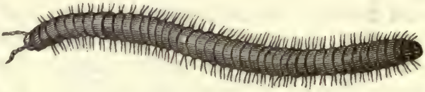


Fig. 171.—Millepede (*Iulus*).

In the common Millepede (*Iulus*) the body is composed of from forty to fifty segments, each of which bears two pairs of minute, thread-like legs. The *Iuli* of this country are of small size, but an American species attains a length of more than half a foot. The *Glomeridæ*, or "Pill-Millepedes," live under stones, and have the power of rolling themselves up into a ball.

ORDER III. PAUROPODA.—In this order is only an extraordinary little *Myriapod*, described by Sir John Lubbock under the name of *Pauropus* (fig. 172). The body is only one-twentieth of an inch in length, and consists of ten somites, furnished with scattered setæ. There are only nine pairs of legs, of which one pair is carried by the 3d segment, whilst the 4th, 5th, 6th, and 7th segments carry each two pairs of legs, and may therefore be regarded as really double. The head is composed of two segments, and is not provided with jaw-feet. The antennæ are five-jointed, bifid, with three long multi-articulate appendages. The body is white and colourless, and there are no tracheæ, so that respiration must be effected entirely by the skin. *Pauropus* is found amongst decaying leaves in damp situations, and species have been described both from Britain and America. It is separated from the *Chilopoda* by its small number of legs, the absence of foot-jaws, and the composition of the antennæ out of no more than five joints.

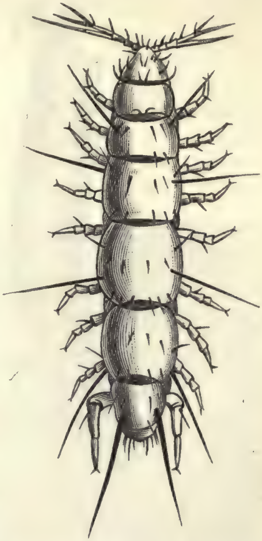


Fig. 172.—*Pauropus Huxleyi*, viewed from above, and enlarged fifty diameters. (After Sir John Lubbock.)

ORDER IV. ONYCHOPHORA (Grube). — In the West Indies, South Africa, South America, and New Zealand occur examples of a peculiar genus of animals, which has been named *Peripatus*, and has been at different times referred to the Errant Annelides, the Leeches, the Tapeworms, or the *Myriapoda*. The species of *Peripatus* are terrestrial in their habits, living in moist earth, in decayed wood, or under stones, active by night only, and completely worm-like in form. The cylindrical body (fig. 173) is annulated, and provided with numerous pairs of ambulatory feet, which are jointed, and terminated by one or two hooked claws (fig. 173, C and D), sometimes with a bunch of setæ. The animal walks like a caterpillar, by means of its feet, and rolls up like a Millepede when alarmed. The mouth is furnished with one or two pairs of horny hooked jaws. The respiratory organs, as recently shown by Moseley, are in the form of *tracheæ*, which open externally by numerous diffused apertures, and rarely branch. From the researches of Moseley, the sexes would appear to be distinct, though the animal is stated to be hermaphrodite by Grube and Hutton. The ventral nerve-cords are widely divergent.

The systematic position of *Peripatus* must in the meanwhile be regarded as doubtful, the animal presenting a type of structure intermediate between the Errant Annelides and the *Myriapoda*. The presence of tracheæ, however, renders it impossible to place *Peripatus* amongst the *Annelida*, and the affinities of the genus appear to be closer with the Myriapods than with any other group; though the wide separation of the ventral nerve-cords, along with other points, removes *Peripatus* to a considerable distance from the normal forms of the *Myriapoda*. If *Peripatus* should ultimately be retained in the *Myriapoda*, it would be as well, for the sake of uniformity, to change Grube's name of *Onychophora* to that of *Onychopoda*.

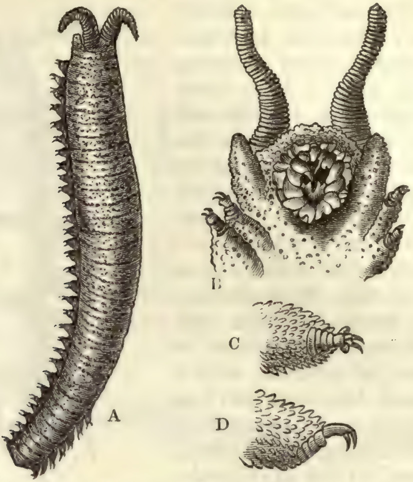


Fig. 173.—A, *Peripatus Edwardsii*, magnified two diameters. B, Head, viewed from below, enlarged five times. C and D, A single foot, viewed from above and sideways, enlarged. (After Grube.)

Distribution of Myriapoda in Time.—About twenty species of *Myriapoda* are known as fossils, the oldest examples of the order having been found in the Carboniferous epoch. From rocks of this age several species of Chilognathous Myriapods have been discovered. The best-known forms belong to the genera *Xylobius* and *Archiulus*, and have been placed in a special family under the name of *Archiulidæ*. The occurrence of air-breathing articulate animals (both *Arachnida* and *Myriapoda*) in the Carboniferous period is noticeable, as being contemporaneous with the earliest-known terrestrial Molluscs.

CHAPTER XXXVIII.

INSECTA.

GENERAL CHARACTERS OF THE INSECTA.

Class IV. Insecta.—The *Insecta* are defined as *articulate animals in which the head, thorax, and abdomen are distinct; there are three pairs of legs borne on the thorax; the abdomen is destitute of legs; a single pair of antennæ is present; mostly, there are two pairs of wings on the thorax. Respiration is effected by tracheæ.*

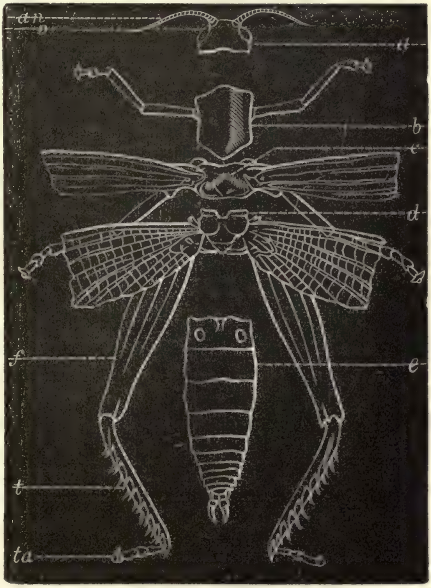


Fig. 174.—Diagram of the external anatomy of an insect. *a* Head carrying the eyes (*o*) and antennæ (*an*); *b* First segment of the thorax, with the first pair of legs; *c* Second segment of the thorax, with the second pair of legs and the first pair of wings; *d* Third segment of the thorax, with the third pair of legs and the second pair of wings; *e* Abdomen, without limbs, but carrying terminal appendages concerned in reproduction; *f* Femur; *t* Tibia; *ta* Tarsus.

In the *Insecta* the body is divided into a variable number of definite segments, or somites, some of which are furnished with jointed appendages, and the nervous and circulatory systems are constructed upon essentially the same plan as in the *Crustacea*, *Arachnida*, and *Myriapoda*. The head, thorax, and abdomen are distinct (figs. 174, 175), and the total number of somites in the body never exceeds twenty. "Of these, five certainly, and six probably" (according to some authorities, four only), "constitute the head, which possesses a pair of antennæ, a pair of mandibles, and two pairs of maxillæ, the hinder pair of which are coalescent, and form the 'labium.' Three, or perhaps, in some cases, more, somites unite and become specially modified to form the thorax, to which the three pairs of locomotive limbs, characteristic of perfect Insects, are attached. Two additional pairs of locomotive organs, the wings, are developed, in most insects, from the tergal walls of the second and third thoracic somites. No locomotive limbs are ever developed from the abdomen of the adult insect; but the ventral portions of the abdominal somites, from the eighth backwards, are often metamorphosed into apparatuses ancillary to the generative function" (Huxley).

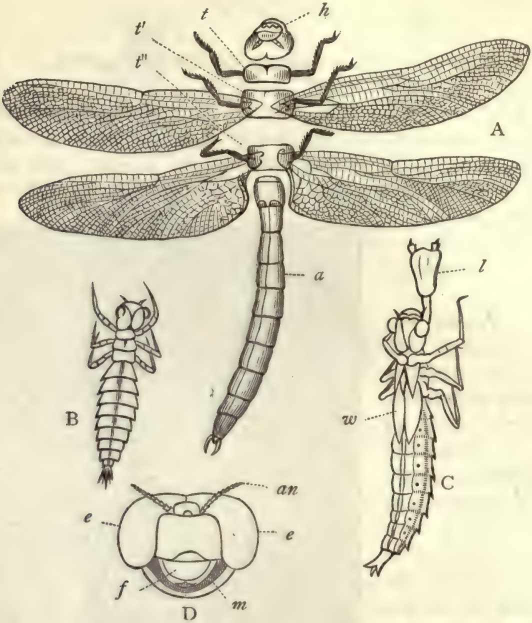


Fig. 175.—A, One of the Dragon-flies (*Æshna grandis*), slightly dissected: *h* Head, carrying the eyes, antennæ, and organs of the mouth; *t t' t''* First, second, and third segments of the thorax slightly separated from one another, each carrying a pair of legs, and the two last carrying each a pair of wings; *a* Tail or abdomen. B, Young form, or "larva," of the same. C, Second stage, or "pupa." D, Head of a Dragon-fly (*Libellula depressa*), showing the feelers or antennæ (*an*), the eyes (*e e*), the hinder pair of jaws (*m*), and the upper lip (*f*).

The integument of the *Insecta*, in the mature condition, is more or less hardened by the deposition of chitine, and usually forms a resisting exoskeleton, to which the muscles are attached. The segments of the head are amalgamated into a single piece, which bears a pair of jointed feelers or antennæ, a pair of eyes, usually compound, and the appendages of the mouth. The segments of the thorax are also amalgamated into a single piece; but this, nevertheless, admits of separation into its constituent three somites (figs. 174, 175). These are termed respectively, from before backwards, the "prothorax," "mesothorax," and "metathorax," and each bears a pair of jointed legs. In the great majority of Insects, the dorsal arches of the mesothorax and metathorax give origin each to a pair of wings.

Each leg consists of from six to nine joints (see fig. 178). The first of these, which is attached to the sternal surface of the thorax, is called the "coxa," and is succeeded by a short joint, termed the "trochanter." The trochanter is followed by a joint, often of large size, called the "femur," succeeded by the so-called "tibia," and this has articulated to it the "tarsus," which may be composed of from one to five joints.

The wings of Insects are expansions of the sides of the meso- and meta-thorax, these expansions being supported by slender but firm tubes, known as the "nervures." Each nervure consists of a central trachea or air-tube, running in the centre of a larger blood-tube; so that the wings not only act as organs of flight, but at the same time assist in the process of respiration. Normally, two pairs of wings are present, but one or other may be wanting. In the *Coleoptera* (Beetles) the anterior pair of wings become hardened by the deposition of chitine, so as to form two protective cases for the hinder membranous wings. In this condition the anterior wings are known as the "elytra," or "wing-cases." In some of the *Hemiptera* this change only affects the inner portions of the anterior wings, the apices of which remain membranous, and to these the term "hemelytra" is applied. In the *Diptera* the posterior pair of wings are rudimentary, and are converted into two capitate filaments, called "halteres" or "balancers." In the *Strepsiptera* the anterior pair of wings are rudimentary, and are converted into twisted filaments.

The typical number of somites in the abdomen of the *Insecta* is eleven, and this number can often be recognised in the *Neuroptera* and in some other forms. In the *Hymenoptera* and *Lepidoptera* not more than ten can be recognised, and in other cases even fewer can be made out. The abdominal somites are usually more or less freely movable upon one another, and never carry locomotive limbs. The extremity of the abdomen is, however, not infrequently furnished with appendages, which are connected with the generative function, and not infrequently serve as offensive and defensive weapons.

Of this nature are the ovipositors of Ichneumons and other insects, and the sting of Bees and Wasps. In the Earwig (*Forficula*) these caudal appendages form a pair of forceps; whilst in many Insects they are in the form of bristles, by which powerful leaps can be effected, as is seen in the Spring-tails (*Poduræ*). In some insects (as the Mole-cricket and Cockroach), the ninth or tenth abdominal segment carries jointed antenniform appendages, which, though perhaps partially or even primarily generative in function, are certainly organs of sense, being connected with smell or hearing.

The organs about the mouth in Insects are collectively termed the "trophi," or "instrumenta cibaria." Two principal types require consideration—namely, the masticatory and the suctorial—both types being sometimes modified, and occasionally combined.

In the Masticatory Insects, such as the Beetles (fig. 176, A), the trophi consist of the following parts, from before backward: 1. An upper lip, or "labrum," attached below the front of the head; 2. A pair of biting-jaws, or "mandibles;" 3. A pair of chewing-jaws, or "maxillæ," provided with one or more pairs of "maxillary palps," or sensory and tactile filaments; 4. A lower lip, or "labium," composed of a second coalescent pair of maxillæ, and also bearing a pair of palpi, the "labial palps." The primitive form of the labium—that, namely, of a second pair of maxillæ—is more or less perfectly retained by the *Orthoptera* and some of the *Neuroptera*.

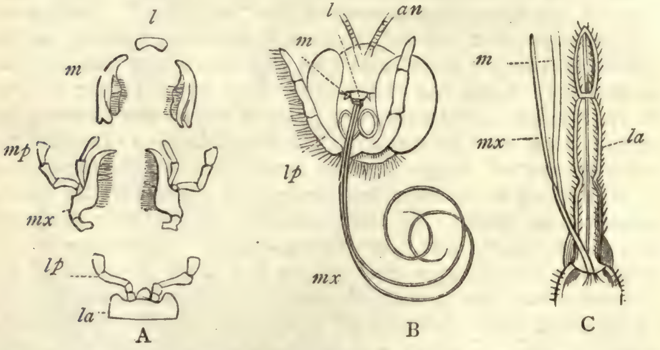


Fig. 176.—Organs of the mouth of Insects, enlarged; (A) of a Beetle (*Carabus*); (B) of the small Cabbage White Butterfly (*Pontia rapæ*); (C) of the Bed-bug (*Cimex lectularius*), the mandibles and maxillæ being displaced to one side. *l* Labrum; *m* Mandible; *mx* Maxilla; *mp* Maxillary palpus; *la* Labium; *lp* Labial palpus; *an* Base of one of the antennæ. (Fig. B is slightly altered from Westwood.)

The lower or basal portion of the labium is called the "mentum," or chin, whilst the upper portion is more flexible, and is termed the "ligula." The central portion of the ligula is often developed into a kind of tongue, which is very distinct in some Insects (as in Bees), and is termed the "lingua."

In the typical suctorial mouth, as seen in the Butterflies (fig. 176, B) the following is the arrangement of parts: The labrum and the mandibles are now quite rudimentary; the first pair of maxillæ is greatly elongated, each maxilla forming a half-tube. These maxillæ adhere together by their inner surfaces, and thus form a spiral "trunk," or "antlia" (inappropriately called the "proboscis"), by which the juices of flowers are sucked up. Each maxilla, besides the half-tube on one side, contains also a tube in its interior; consequently on a transverse section the trunk is found really to consist of three canals, one in the interior of each maxilla, and the third formed between them by their apposition. To the base of the trunk are attached the maxillary palpi, which are extremely small. Behind the trunk is a small labium, composed of the united second pair of maxillæ. The "labial palpi" are greatly developed, and form two hairy cushions, between which the trunk is coiled up when not in use.

In the Bee there exists an intermediate condition of parts, the mouth being fitted partly for biting, and partly for suction. The labrum and mandibles are well developed, and retain their usual form. The maxillæ and the labium are greatly elongated; the former being apposed to the lengthened tongue in such a manner as to form a tubular trunk, which cannot be rolled up, as in the Butterflies, but is capable of efficient suction. The labial palpi are also greatly elongated.

In the *Hemiptera*, the "trophi" consist of four lancet-shaped needles, which are the modified mandibles and maxillæ, enclosed in a tubular sheath formed by the elongated labium (fig. 176, C). Lastly, in the *Diptera*—as in the common House-fly—there is an elongated labium, which is channelled on its upper surface for the reception of the mandibles and maxillæ, these being modified into bristles or lancets.

The mouth in the Masticating Insects leads by a pharynx and œsophagus into a membranous, usually folded, stomach—the "crop," or "ingluvies"—from which the food is transmitted to a second muscular stomach, called the "gizzard" (fig. 177). The gizzard, or proventriculus, is adapted for crushing the food, often having plates or teeth of chitine developed in its walls, and is succeeded by the true digestive cavity, called the "chylific stomach" (*ventriculus chylopoieticus*).

From this an intestine of variable length proceeds, its terminal portion, or rectum, opening into a dilatation which is common to the ducts of the generative organs, and is termed the "cloaca." The œsophagus is furnished with salivary glands of varying size and complexity, which open into the cavity of the mouth. Besides the proper salivary glands, the larvæ of Insects very usually possess a pair of silk-glands, which discharge their secretion by a single duct, furnished with a spinneret, and developed upon the labium. Rarely (as in *Myrmeleo*), there are silk-glands opening in the abdominal region. Those silk-glands which open into the mouth are to be regarded as modified salivary glands, and they are almost invariably confined to the larvæ. No true liver is present, but the stomach is lined by secreting cells, which appear to exercise an hepatic function. Behind the pyloric aperture of the stomach, with very few exceptions, is a variable number of cæcal convoluted tubes (fig. 177, *e*), which open into the intestine, and are called the "Malpighian tubes." These vessels are now generally regarded as discharging a renal function, and as corresponding with the kidneys of the higher animals. There are no absorbent vessels, and the products of digestion simply transude through the walls of the alimentary canal into the sinuses or irregular cavities which exist between the abdominal organs. The apparatus of digestion does not differ essentially from the above in any of the Insects; but the alimentary canal is, generally speaking, considerably lengthened in the herbivorous species.

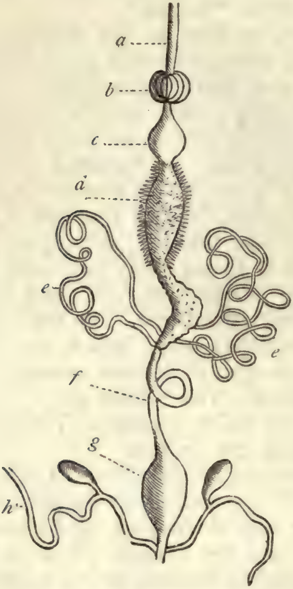


Fig. 177.—Digestive system of a Beetle (*Carabus auratus*). *a* Œsophagus; *b* Crop; *c* Gizzard; *d* Chylific stomach; *e* Malpighian tubes; *f* Intestine; *g* Cloaca; *h* Anal glands.

There is no regular and definite course of the circulation in the Insects. The propulsive organ of the circulation is a long contractile cavity, situated in the back and termed the "dorsal vessel" (fig. 178, *h*). This is composed of a number of sacs (ordinarily eight), opening into one another by valvular apertures, which allow of a current in one direction only—viz., towards the head. The blood is collected from the irregular venous sinuses which are formed by the lacunæ and interstices between the tissues, and enters the dorsal vessel from behind, and by lateral valvular openings; it is then driven forwards, and is expelled at the anterior extremity of the body. The blood of the *Insecta* is corpusculated, and usually colourless. Whilst the general belief is that there is no regular system of blood-vessels (arteries and veins), and that the blood simply circulates through the interstices of the tissues, some observers affirm the partial existence of true vessels, and others maintain that the blood circulates in the spaces between the tracheæ and their enveloping sheaths, which thus become converted into blood-vessels.

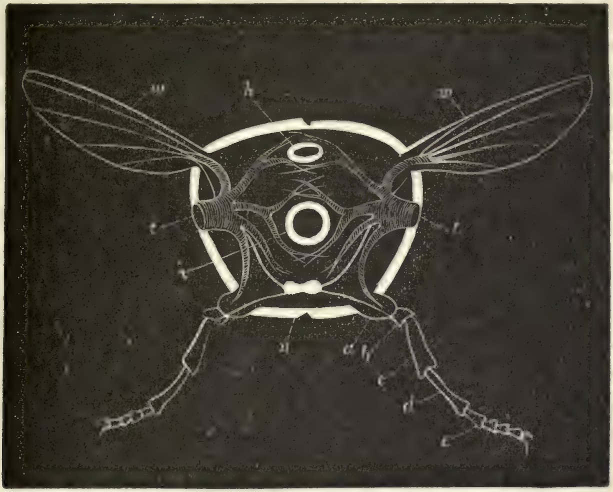


Fig. 178.—Ideal transverse section of an Insect. *h* Dorsal vessel; *i* Intestine; *n* Ventral Nerve-cord; *t t* Stigmata, leading into the branched tracheal tubes; *w w* Wings; *a* Coxa of one leg; *b* Trochanter; *c* Femur; *d* Tibia; *e* Tarsus. (After Packard.)

Respiration is effected by means of "tracheæ," or branched tubes, which commence at the surface of the body by lateral apertures, called "stigmata," or "spiracles," and ramify through every part of the animal. In structure the tracheæ are membranous, but their walls are strengthened by a chitinous filament, which is rolled up into a continuous spiral coil. In the aquatic larvæ of many insects, and in one or two adult Insects (in *Pteronarcys*, one of the *Orthoptera*, and in one of the *Phasmidæ*, of the same order) branches of the tracheæ are sent to variously-shaped outgrowths which are termed "tracheal gills," and in which the blood is oxygenated. In all, however, with the exceptions above mentioned, these temporary internal or external appendages fall off when maturity is attained. The wings, also, whilst acting as locomotive organs, doubtless subserve respiration, the nervures being hollow tubes filled with blood and enclosing tracheæ.

Entomologists have generally recognised the following kinds of breathing-organs in Insects :—

1. The true tracheæ, in the form of branched tubes, the walls of which are strengthened by a chitinous fibre.
2. Tracheal vesicles, or dilated receptacles directly connected with the proper tracheæ, but having membranous walls not supported by a horny spiral fibre.
3. The modified tracheæ of some adult *Hemiptera* and various aquatic larvæ, in which the lips of the stigmata are prolonged into shorter or longer external tubes, by which the air is conveyed to the interior.
4. The tracheal gills properly so called, these usually being leaf-like plates attached to the sides of the abdomen, or tuft-like processes developed from the mucous membrane of the rectum.

The nervous system in Insects, though often concentrated into special masses, consists essentially of a chain of ganglia, placed ventrally, and united together by a series of double cords or commissures. The cephalic or "præ-œsophageal" ganglia are of large size, and distribute filaments to the eyes and antennæ. The post-œsophageal ganglia are united to the preceding by cords which form a collar round the gullet, and they supply the nerves to the mouth, whilst the next three ganglia furnish the nerves to the legs and wings. In larvæ, thirteen pairs of ganglia may often be recognised. In the adults, however, of the higher groups of Insects (such as the *Coleoptera*, *Hymenoptera*, *Diptera*, and *Lepidoptera*), the thoracic ganglia coalesce into a single mass.

The organs of sense are the eyes and antennæ. The eyes in Insects are usually "compound," and are composed of a number of hexagonal lenses, united together, and each supplied with a separate nervous filament. Besides these, simple eyes—"ocelli," or "stemmata,"—are often present, or, in rare cases, may be the sole organs of vision. In structure these resemble the single elements of the compound eyes. In a few cases the eyes are placed at the extremities of stalks or peduncles, but in no case are these peduncles movably articulated to the head, as is the case in the Podophthalmous Crustaceans.

The antennæ are movable, jointed filaments, attached usually close to the eyes, and varying much in shape in different Insects. They doubtless discharge the functions of tactile organs, but are probably the organ of other more recondite senses in addition.

The sexes in Insects are in different individuals, and most are oviparous. The ovum undergoes partial segmentation; and the embryo has its future ventral surface turned outwards, and its dorsal surface inwards. Generally speaking, the young insect is very different in external characters from the adult, and it requires to pass through a series of changes, which constitute the "metamorphosis," before attaining maturity. In some Insects, however, there appears to be no metamorphosis, and in some the changes which take place are not so striking or so complete as in others. By the absence of metamorphosis, or by the degree of its completeness when present, Insects are divided into sections, called respectively *Ametabola*, *Hemimetabola*, and *Holometabola*, which, though not, perhaps, of a very high scientific value, are nevertheless very convenient in practice.

Section 1. *Ametabolic Insects.*—These pass through no metamorphosis, and also, in the mature condition, are destitute of wings. The young of these insects (*Aptera*) on escaping from the ovum resemble their parents in all respects except in size; and though they may change their skins frequently, they undergo no alteration before reaching the perfect condition, except that they grow larger.

Section 2. *Hemimetabolic Insects.*—In the insects belonging to this section there is a metamorphosis consisting of three stages. The young on escaping from the ovum is termed the "larva;" when it reaches its second stage it is called the "pupa," or "nymph;" and in its third stage, as a perfect insect, it is called the "imago." In the *Hemimetabola*, the "larva," though of course much smaller than the adult, or "imago," differs from it in little else except in the absence of wings. It is active and locomotive, and is generally very like the adult in external appearance. The "pupa," again, is a little larger than the larva, but really differs from it in nothing else than in the fact that the rudiments of wings have now appeared, in the form of lobes enclosed in cases. The "pupa" is still active and locomotive, and the term "nymph" is usually applied to it. The pupa is converted into the perfect insect, or "imago," by the liberation of the wings, no other change being requisite for this purpose. From the comparatively small amount of difference between these three stages, and from the active condition of the pupa, this kind of metamorphosis is said to be "incomplete."

In some members of this section, however—such as the Dragon-flies — the larva and pupa are aquatic, whereas the imago leads an aerial life. In these cases (fig. 175) there is necessarily a considerable difference between the larva and the adult; but the larva and pupa are closely alike, and the latter is active.

Section 3. *Holometabolic Insects.* — These — comprising the Butterflies, Moths, Beetles, &c.—pass through three stages which differ greatly from one another in appearance, the metamorphosis, therefore, being said to be "complete." In these insects (fig. 179) the "larva" is vermiform, segmented, and usually provided with locomotive feet, which do not correspond with those of the adult, though these latter are usually present as well (fig. 179). In some cases the larva is destitute of legs, or is "apodal." The larva is also provided with masticatory organs, and usually eats voraciously. In this stage of the metamorphosis the larvæ constitute what are usually called " caterpillars " and " grubs." Having remained in this condition for a longer or shorter length of time, and having undergone repeated changes of skin, or "moults," necessitated by its rapid growth, the larva passes into the second stage, and becomes a "pupa." The insect is now perfectly quiescent, unless touched or otherwise irritated; is incapable of changing its place; and is often attached to some foreign object. This constitutes what—in the case of the *Lepidoptera*—is generally known as the "chrysalis," or "aurelia" (fig. 179). The body of the pupa is usually covered by a chitinous pellicle, which closely invests the animal. In some cases (*e.g.*, in many Dipterous insects) no traces of the future insect can be detected in the pupa by external inspection; but in the *Lepidoptera* the

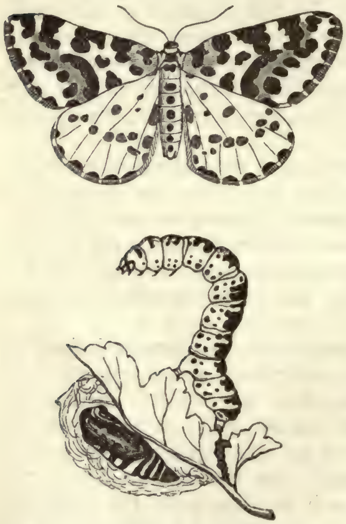


Fig. 179.—Metamorphosis of the Magpie-moth (*Phalæna grossulariata*).

thorax and abdomen are distinctly recognisable in the pupæ; whilst in others (*e.g.*, *Hymenoptera*) the parts of the pupa are merely covered by a membrane, and are quite distinct. In some cases the pupa is further protected within the dried skin of the larva; and in other cases the larva—immediately before entering upon the pupa-stage—spins, by means of special organs for the purpose, a protective case, which surrounds the chrysalis, and is termed the "cocoon."

Having remained for a variable time in the quiescent pupa-stage, and having undergone the necessary development, the insect now frees itself from the envelope which obscured it, and appears as the perfect adult, or "imago," characterised by the possession of wings.

SEXES OF INSECTS.—The great majority of Insects, as is the case with most of the higher animals, consist of male and female individuals; but there occur some striking exceptions to this rule, as seen in the Social Insects. In those organised communities which are formed by Bees, Ants, and Termites, by far the greater number of the individuals which compose the colony are either undeveloped females, or are of no fully developed sex. This is the case with the workers amongst Bees, and the workers and soldiers amongst Ants and Termites. And, these sterile individuals, or "neuters," as they are commonly called, are not necessarily all alike in structure and external appearance. Amongst the Bees, all the neuters resemble one another; but amongst Ants and Termites they are often divided into "castes," which have different functions to perform in the general polity, and differ from one another greatly in their character.

The organs of the two sexes are in no case united in the same individual, or, in other words, there are no hermaphrodite insects. (In some abnormal cases amongst Bees, *Lepidoptera*, &c., hermaphrodite individuals have been observed.) As has been noticed, however, before, asexual reproduction is by no means unknown amongst the *Insecta*, and the attendant phenomena are often of extreme interest. (See Introduction.)

DISTRIBUTION IN SPACE.—The great majority of Insects, during their adult condition, are terrestrial or aerial in their habits, but in many cases, even of these, the larvæ are aquatic. Many other insects live habitually during all stages of their existence in fresh water. A few insects inhabit salt water (either the sea itself or inland salt waters) during the whole or a portion of their existence. (This is the case with two or three Beetles of the families *Hydrophilidæ* and *Dytiscidæ*, some Hemipterous Insects, and the larvæ of various *Diptera*.) Lastly, many insects live parasitically upon the bodies of Birds or Mammals, or upon other Insects.

DISTRIBUTION OF INSECTS IN TIME.—The most ancient remains of Insects at present known to us are from the Devonian rocks of North America. Here occur several forms apparently belonging to the *Neuroptera* (or *Pseudo-neuroptera*), In the Carboniferous rocks the remains of Insects are more abundant, and we find examples of several orders (such as the *Coleoptera*, *Orthoptera*, and *Neuroptera*). The orders *Hymenoptera* and *Lepidoptera* are not certainly known to occur till the Secondary period is reached; and in the Tertiary rocks we find representatives of almost all the existing orders. Amber, which is a fossil resin, has long been known to contain many insects in its interior (in certain specimens); and all of these appear to belong to extinct species, though amber, geologically speaking, is not an ancient product.

CHAPTER XXXIX.

DIVISIONS OF INSECTA.

THE class *Insecta* includes such an enormous number of species, genera, and families, that it would be impossible to treat of these satisfactorily otherwise than in a treatise especially devoted to entomology. Here it will be sufficient to give simply the differential characters of the different orders, drawing attention occasionally to any of the more important points in connection with any given family.

As already said, the *Insecta* are divided into three divisions, termed *Ametabola*, *Hemimetabola*, and *Holometabola*, according as they attain the adult condition without passing through a metamorphosis, or have an incomplete or complete metamorphosis. The Insects which come under the first head (viz., *Ametabola*) are not furnished with wings in the adult condition, and the four orders which compose this section are commonly grouped together under the name *Aptera*. By some, however, this division is entirely rejected, and the orders in question are placed amongst the *Hemimetabola*, or even grouped with the *Myriapoda*. Indeed, it is certain that the orders of the so-called Apterous Insects are not, strictly speaking, scientific divisions. It is, however, a matter of convenience to retain them in a separate form, as it is by no means absolutely certain how they may most naturally be distributed amongst the higher orders.

SUB-CLASS I. AMETABOLA.—*Young not passing through a metamorphosis, and differing from the adult in size only. Imago destitute of wings; eyes simple, sometimes wanting.*

ORDER I. ANOPLURA.—*Minute Aptera, in which the mouth is formed for suction; and there are two simple eyes.*

This order comprises insects which are commonly parasitic upon man and other animals, and are known as Lice (*Pediculi*). The common Louse (fig. 180, A) is furnished with a simple eye, or ocellus, on each side of a distinctly differentiated head, the under surface of which bears a suctorial mouth. There is little distinction between the thorax and abdomen, but the segments of the former carry three pairs of legs. The legs are short, with short claws or with two opposing hooks, affording a very firm hold. The body is flattened and nearly transparent, distinctly segmented, and showing the stigmata very plainly. The young pass through

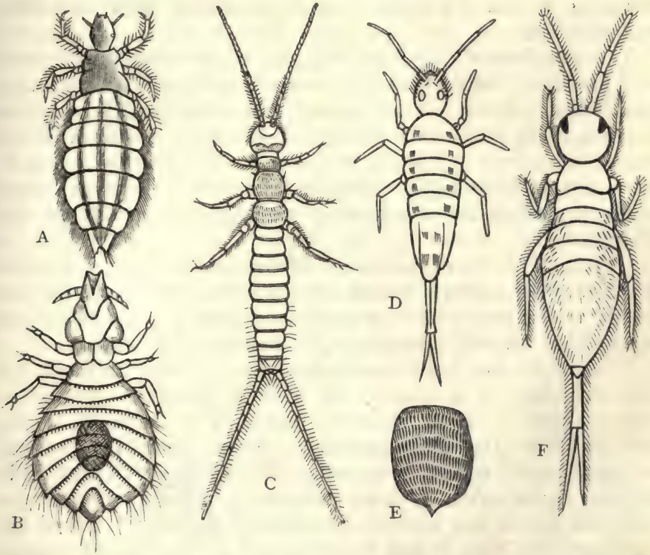


Fig. 180.—Morphology of Aptera. A, *Pediculus humanus capitis*; B, *Docophorus hamatus*, one of the Bird-lice; C, *Campodea*; D, *Degeeria*, one of the *Poduridæ*; E, Scale of a Podurid, as seen under the microscope; F, *Degeeria purpurascens*. All the figures are greatly enlarged. (After Packard and Gervais.)

no metamorphosis, and their multiplication is extremely rapid. Many Mammals are infested by Lice, the same animal often being subject to the attacks of more than one species of Louse. Three species commonly attack man—viz., *Pediculus humanus corporis*, *P. capitis*, and *P. pubis*; and a fourth species (*P. tabescentium*) is of rare occurrence, and gives rise to the loathsome disease known as Phthiriasis.

The Lice are now very commonly associated with the *Hemiptera*, of which they are regarded as constituting a degraded and aberrant group.

ORDER II. MALLOPHAGA.—*Minute Aptera, in which the mouth is formed for biting, and is furnished with mandibles and maxillæ.*

The members of this order (fig. 180, B) are commonly known as "Bird-lice," being parasitic, sometimes upon Mammals, but mostly upon Birds. They strongly resemble the *Pediculi*, but the mouth is formed for biting, to suit their mode of life—since they do not live upon the juices of their hosts, but upon the more delicate tegumentary appendages. They are sometimes regarded as constituting a degraded group of the *Hemiptera.*

ORDER III. COLLEMBOLA.—*Minute Aptera, with a semi-masticatory or suctorial mouth; the first abdominal segment furnished with a ventral tube or suctorial organ; the last abdominal segment but one with appendages for leaping.*

This order has been established by Sir John Lubbock for the reception of a number of Insects generally known as "Spring-tails." Their scientific name is in allusion to the fact that they attach themselves to foreign bodies by a ventral suctorial tube, which contains a viscous fluid; whilst their popular name refers to their possessing saltatory appendages attached to the last abdominal segment but one. These appendages (fig. 180, D and F) consist of a long forked process which is generally bent along the under surface of the body, and kept there by a small catch. When released, the sudden extension of the elastic process throws the insect into the air. The body is covered either with hairs or scales, and the latter exhibit under the microscope very elaborate and beautiful markings (fig. 163, E). They are generally to be found in moist dark places in gardens, or on the surface of pools, and the commonest genera are *Podura*, *Smynthurus*, and *Degeeria.*

ORDER IV. THYSANURA.—*Minute Aptera, with a masticatory mouth; the end of the abdomen furnished with long bristle-like terminal appendages, used in locomotion.*

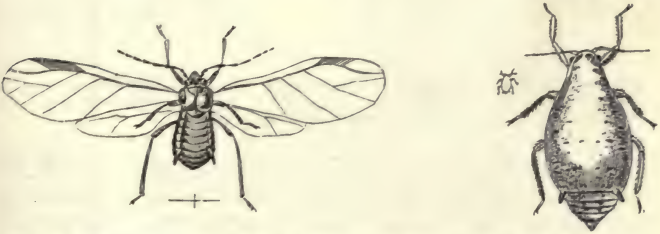
The Insects of this order are closely related to those of the preceding, but the long anal bristles do not form a "spring;" and the mouth is distinctly masticatory. The two principal genera are *Lepisma* and *Campodea* (fig. 180, C), both of which live generally under stones or in dark situations. The body is hairy, or clothed with metallic scales; these latter organs being in *Lepisma* so delicately marked that they are commonly used as test-objects for the microscope.

According to Packard, the *Thysanura* and *Collembola* are to be regarded as degraded groups of *Neuroptera*, the former having also affinities with the *Myriapoda*. According to Sir John Lubbock, *Campodea* may be regarded as a modern representative of an ancient type-form, from which the higher Insects originally took their rise.

SUB-CLASS II. HEMIMETABOLA.—*Metamorphosis incomplete; the larva differing from the imago chiefly in the absence of wings, and in size; pupa usually active, or, if quiescent, capable of movement.**

ORDER V. HEMIPTERA (*Rhynchota*).—*Mouth suctorial, beak-shaped, consisting of a jointed rostrum, composed of the elongated labium, which forms a jointed, tubular sheath for the bristle-shaped, styliform mandibles and maxillæ. Eyes compound, usually with ocelli as well. Two pairs of wings in most; sometimes wanting. Pupa generally active.*

The *Hemiptera* live upon the juices of plants or animals, which they are enabled to obtain by means of the suctorial rostrum.



Fig, 181.—Hemiptera. Bean Aphis (*Aphis fabæ*), winged male and wingless female.

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* The *Coccidæ*, amongst the *Hemiptera*, undergo a complete metamorphosis. In certain of the *Hemiptera* and *Orthoptera* the adult is apterous, and in these cases there cannot be said to be any metamorphosis, since the larvæ differ from the adult only in size, in having fewer joints to the antennæ, and in having a smaller number of facets in each of the compound eyes.

The order is divided into the following three sub-orders:—

Sub-order a. Homoptera.—The anterior pair of wings of the same texture throughout (membranous); the mouth turned backwards, so that the beak springs from the back of the head. The wings fold over one another when the insect is at rest. There are ocelli between the compound eyes, and the antennæ are small and composed of few joints. The females often have an ovipositor of three toothed blades. In this section are the Aphides, the Scale Insects (*Coccidæ*), the Cicadas, the Lantern-flies (*Fulgora*), &c.

As typical examples of the *Homoptera* may be taken the *Cicadas* (fig. 182, D), the males of which are well known for their power of emitting a musical note or chirp. The Plant-lice or *Aphides* (fig. 181) live upon the juices of plants, an enormous number of species being known. They may possess two pairs of membranous wings, or none, and they give birth to innumerable young in the summer months by a process of parthenogenesis. The singular Scale-insects (*Coccidæ*) have the males winged, whilst the females are deformed, often scale-like, and devoid of wings. The dried female of the Cochineal Insect (*Coccus cacti*) constitutes the cochineal of commerce, and the *Coccus lacca* yields shell-lac.

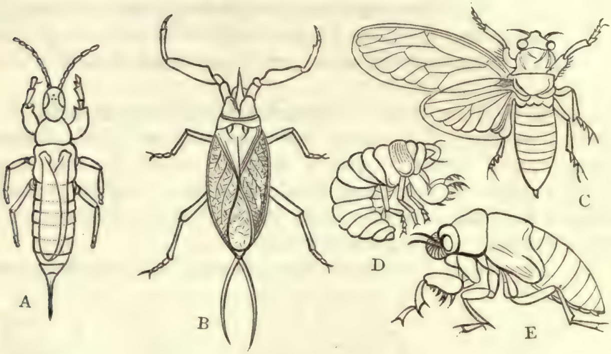

Fig. 182.—A, *Thrips*, enlarged; B, *Nepa cinerea*, enlarged; C, *Cicada Anglica*, the wings on the right side of the body being omitted; D, Larva of the same; E, Pupa of the same. (Figs. C, D, and E are after Westwood.)

Sub-order b. Heteroptera.—Anterior wings membranous near their apices, but chitinous towards the base (hemelytra); the rostrum springing from the front of the head. The inner margins of the wings are straight or contiguous. The antennæ are moderate in size, and composed of a few large joints. They are divided into the two groups of the *Hydrocorisæ* (Water-bugs) and *Geocorisæ* (Land-bugs), according as they are aquatic or mainly terrestrial in their habits.

Amongst well-known members of this group may be mentioned the Forest-bugs and Field-bugs (*Pentatoma*, and its allies), the Bed-bug (*Cimex lectularius*), the Boat-fly (*Notonecta*), the Water-scorpions (*Nepa*, fig. 182, B), and the Water-spiders (*Hydrometra*).

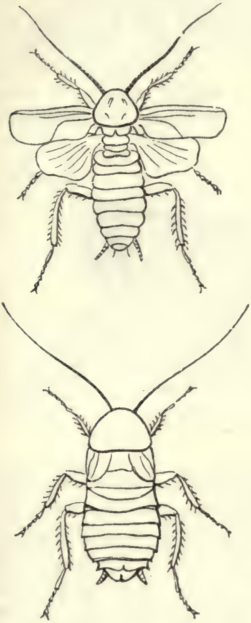

Fig. 183.—Orthoptera. The common Cockroach (*Blatta orientalis*), male and female.

Sub-order c. Thysanoptera.—Mouth with mandibles and maxillæ, furnished with palpi. The wings with few or no nervures, fringed. In this sub-order are only the little insects which form the genus *Thrips* (fig. 182, A), and some allied forms. They live upon plants, and differ from the typical *Hemiptera* both in the structure of the wings, and in the fact that the beak-like rostrum really contains palpate mandibles and maxillæ.

ORDER VI. ORTHOPTERA.—*Mouth masticatory; wings four, sometimes wanting; the anterior pair mostly smaller than the posterior, semi-coriaceous or leathery*, usually with numerous nervures, the interspaces between which are filled with many transverse reticulations; sometimes overlapping horizontally (Cockroach), sometimes meeting like the roof of a house (Grasshoppers). *Posterior wings usually having their front portion of a different texture from their hinder portion*, this latter being almost always more transparent, and *when not in use folded longitudinally like a fan.* Posterior wings often wanting in the females of the *Blattidæ.* Antennæ usually filiform. Metamorphosis semi-incomplete (sometimes, however, the adult is apterous, when it becomes almost impossible to distinguish the larva, pupa, and imago).

This order includes a number of well-known insects, most of which are vegetable-feeders. Some of the *Orthoptera*, such as the Cockroaches (*Blattidæ*, fig. 183) have slender legs, and are adapted for running (*cursorial*). Others are suited for walking, and are said to be *gressorial.* Amongst these are the *Mantides*, with their great raptorial front-legs, and the singular Walking Leaves and Stick-insects (the *Phasmidæ*). Others, again, are *saltatorial*, having the hind-legs elongated and adapted for leaping, In this section are the Crickets and Mole-crickets (*Gryllidæ* or *Achetidæ*), and the Grasshoppers and Locusts (*Acridiidæ* and *Locustidæ*). The Saltatory *Orthoptera* are all vegetable-feeders, and whilst many of them commit serious depredations upon green crops and grass, the ravages of the Migratory Locust (*Œdipoda migratoria*, fig. 184) are in this respect unrivalled. Finally, there is a small section of the *Orthoptera*, which includes the Earwigs (*Forficulidæ*), and which has been raised to the rank of a distinct order under the name of *Euplexoptera.* In this group, the last segment of the abdomen carries a pair of nippers, and the anterior wings are very short, the posterior wings are membranous, and are folded up both longitudinally and transversely, being useless for flight.

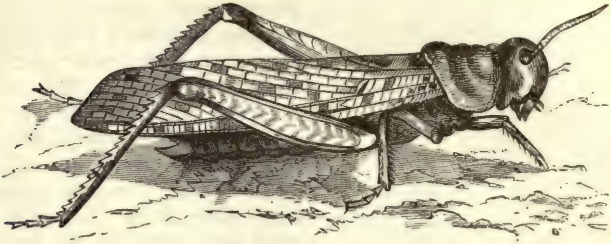

Fig. 184.—Migratory Locust (*Œdipoda migratoria*).

ORDER VII. NEUROPTERA (*Odonata*).—*Mouth usually masticatory; wings, four in number, all membranous, generally nearly equal in size, traversed by numerous delicate nervures, having a longitudinal and transverse direction, and giving them a reticulated, lace-like aspect. Metamorphosis generally incomplete, rarely complete. The larva active, hexapod, the pupa active or quiescent.*

The order *Neuroptera* includes a number of Insects which are so different in their characters, habits, and metamorphoses, that they are sometimes placed in three separate and special groups. The first section includes what may be termed normal *Neuroptera*, such as the Ant-lions (*Myrmeleontidæ*), the Aphis-lions (*Hemerobiidæ*, fig. 185), the Scorpion-flies (*Panorpidæ*), and the *Sialidæ*. The second section includes the Dragon-flies (*Libellulidæ*), the May-flies (*Ephemeridæ*), the Stone-flies (*Perlidæ*), the White Ants (*Termitidæ*), and some less important families. These are often placed in the *Orthoptera*, under the common name of *Pseudoneuroptera*. Lastly, we have a section sometimes elevated to the rank of a distinct order under the name of *Trichoptera*, for the reception of the singular Caddis-flies (*Phryganeidæ*). In this group the anterior wings are generally hairy, the mandibles are rudimentary, the larva usually resides in a case formed of small foreign bodies, and the pupa is inactive during the greater part of its life.

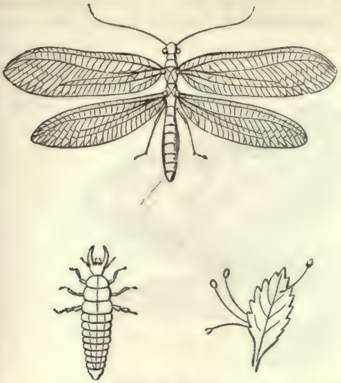

Fig. 185.—Neuroptera. Aphis-lion (*Chrysopa perla*), imago, larva, and eggs.

Amongst the more remarkable of the *Neuroptera* are the so-called "White Ants" or Termites, a brief description of which may be given here. The Termites are social insects, living in organised communities, and they are mostly inhabitants of hot countries. (It must be borne in mind that though often called "White Ants," they stand in no relation to the true Ants.) Mr Bates has given us an excellent description of the habits of these singular insects, from which much of what follows has been taken.

Termites are small, soft-bodied insects, which live in large communities, as do the true Ants. They differ, however, from the Ants in the fact that the workers are individuals of no fully-developed sex, whereas amongst the latter they are undeveloped females. Further, the neuters of the Termites are always composed of two distinct classes or "castes"—the workers and the soldiers. Lastly, the Ants undergo a quiescent pupa-stage; whereas the young Termites, on their emergence from the egg, do not differ from the adult in any respect except in size.

Each species of Termites consists of several distinct orders or castes, which live together, and constitute populous, organised communities. They inhabit structures known as "Termitaria," consisting of mounds or hillocks, some of which are "five feet high, and are formed of particles of earth worked into a material as hard as stone." The Termitarium has no external aperture for ingress or egress, as far as can be seen, the entrance being placed at some distance, and connected with the central building by means of covered ways and galleries. Each Termitarium is composed of "a vast number of chambers and irregular intercommunicating galleries, built up with particles of earth or vegetable matter, cemented together with the saliva of the insects." Many of "the very large hillocks are the work of many distinct species, each of which uses materials differently compacted, and keeps to its own portion of the tumulus."

A family of Termites consists of a king and queen, of the workers, and of the soldiers. According to the researches of Lespès, Bates, and Fritz Müller, the workers and soldiers amongst the Termites are not sterile females, but *modified larvæ*, which belong to both sexes, and are arrested in their development (or, rarely, males and females in which the reproductive organs are rudimentary). Fritz Müller has further discovered that, in addition to the winged males and females which are periodically produced in great numbers, there exists in some, if not in all, of the species a second set of males and females, which are destitute of wings. These complementary males and females never leave the termitary in which they are born; and they may take the place of the winged males and females whenever a community fails to secure a royal couple at the proper period. The royal couple are the parents of the colony, and "are always kept together, closely guarded by a detachment of workers, in a large chamber in the very heart of the hive, surrounded by much stronger walls than the other cells. They are both wingless, and immensely larger than the workers and soldiers. The queen, when in her chamber, is always found in a gravid condition, her abdomen enormously distended with eggs, which, as fast as they come forth, are conveyed, by a relay of workers, in their mouths, from the royal chamber to the minor cells dispersed through the hive."

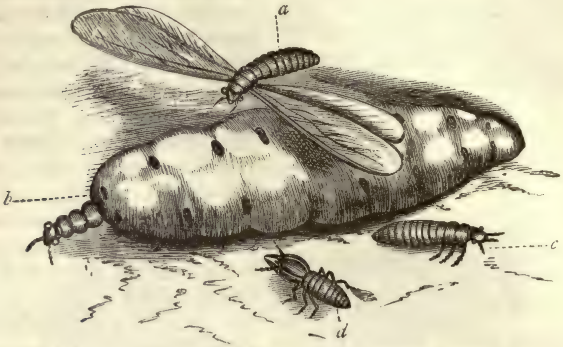

Fig. 186.—Termites (*Termes bellicosus*). *a* King, before the wings are cast off; *b* Queen, with the abdomen distended with eggs; *c* Worker; *d* Soldier.

At the beginning of the rainy season a number of *winged* males and females are produced, which, when they arrive at maturity, leave the hive, and fly abroad. They then shed their wings (a special provision for this existing in a natural seam running across the root of the wing and dividing the nervures); they pair, and then become the kings and queens of future colonies.

The workers and the soldiers are distinct from the moment of their emergence from the egg, and they do not acquire their special characteristics in consequence of any difference of food or treatment. Both are wingless, and they differ solely in the armature of the head. The duties of the workers are to "build, make covered roads, nurse the young brood from the egg upwards, take care of the king and queen, who are the progenitors of the whole colony, and secure the exit of the males and females when they acquire wings, and fly out to pair and disseminate the race." The duties of the soldiers are to defend the community from all attacks which may be made upon its peace, for which purpose the mandibles are greatly developed.

SUB-CLASS III. HOLOMETABOLA.—*Metamorphosis complete; the larva, pupa, and imago differing greatly from one another in external appearance. The larva vermiform, and the pupa quiescent.*

ORDER VIII. APHANIPTERA. — *Wings rudimentary, in the form of scales, situated on the mesothorax and metathorax. Mouth suctorial. Metamorphosis complete.*

This order comprises the Fleas (*Pulicidæ*), which are parasitic upon different animals. The larva of the common Flea (*Pulex irritans*, fig. 187) is an apodal grub, which in about twelve days spins a cocoon for itself, and becomes a quiescent pupa, from which the imago emerges in about a fortnight more.

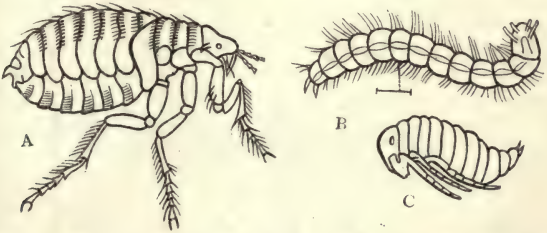

Fig. 187.—A, The common Flea (*Pulex irritans*); B, Larva of the same; C, Pupa of the same. All the figures are greatly magnified. (After Westwood.)

The Chigoe or Sand-flea (*Sarcopsylla penetrans*) of the tropical parts of America, is a more serious pest than the common Flea. It is, however, only a parasite as regards the impregnated females; the males, unimpregnated females, and larvæ leading a free existence. The impregnated females, however, bore their way through the skin of the foot in the human subject, and live there till they assume the size of peas, by the distension of the abdomen with eggs, often occasioning great local irritation and inflammation. They also live beneath the skin of mice and dogs.

Many authorities regard the *Aphaniptera* as a degraded group of the *Diptera*.

ORDER IX. DIPTERA.—*The anterior pair of wings alone developed; the posterior pair of wings rudimentary, represented by a pair of clubbed filaments, called "halteres," or "balancers"* (fig. 188). *In a few the wings are altogether wanting. Mouth suctorial. The metamorphosis is complete, the larvæ being generally destitute of feet; but in some cases* (e.g., *the gnats*) *the pupæ are aquatic and are actively locomotive. In most cases, however, the pupæ are quiescent.*

The proboscis in the *Diptera* consists of a tubular labium enclosing the other parts of the mouth, and is placed on the under surface of the head. Ocelli are present in addition to the compound eyes. The wings are generally horizontal and transparent, the nervures not very numerous, and for the most part longitudinally disposed. The anterior wings usually have appended to their hinder margin, at their base, a pair of little membranous flaps (the "alulæ"), which are to be regarded as separate and detached elements of the front wings. The antennæ are generally small and three-jointed (*Brachycera*), sometimes many-jointed (*Tipulidæ*), or feathery (*Culicidæ*). The larva is soft and fleshy, with a soft indistinct head, usually apodal, never with thoracic legs, and rarely with pro-legs. The larval skin mostly forms a hardened case for the pupa, but the larvæ sometimes cast their skin when becoming pupæ,

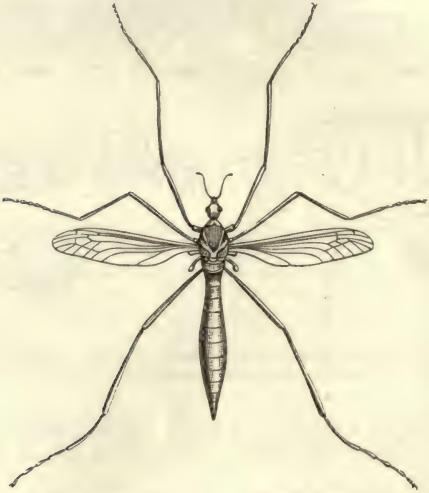

Fig. 188.—Diptera. Crane-fly (*Tipula oleracea*).

or even spin cocoons. In one section of the *Diptera*, hence termed *Pupipara*, the larvæ continue to reside within the mother until they are just ready to become pupæ, and they are born in a form closely resembling the ordinary pupæ of the members of the order. In the Hessian Fly (*Cecidomyia*) the larva produces asexually a number of secondary larvæ, which are developed within the body of the primitive larva, and feed upon its tissues, ultimately causing its death.

The *Diptera* constitute one of the largest of the orders of the *Insecta*. Amongst the more important forms included in this division may be enumerated the House-flies, Bluebottles, and Flesh-flies (*Muscidæ*); the Gnats, Midges, and Mosquitos (*Culicidæ*); the Bot-flies (*Œstridæ*); the Gad-flies (*Tabanidæ*); the Forest-flies and Sheep-ticks (*Hippoboscidæ*); and the Crane-flies (*Tipulidæ*).

ORDER X. LEPIDOPTERA.—*Mouth suctorial, consisting of a spiral trunk or "antlia," composed of the greatly-elongated maxillæ, and protected, when not in use, by the cushion-shaped hairy labial palpi. Maxillæ forming two sub-cylindrical tubes, united together by inosculating hooks, and constituting an intermediate tube by their junction. Maxillary palpi minute; labrum and mandibles rudimentary. Head, thorax, and abdomen more or less covered with hair. Wings, four in number, covered with modified hairs or scales; wanting in the females of a few species. Nervures not very numerous, mostly longitudinal. Antennæ composed of numerous minute joints.*

This well-known and most beautiful of all the orders of Insects comprises the Butterflies (fig. 189) and the Moths (fig. 190); the former being diurnal in their habits, the latter mostly crepuscular or nocturnal.

The larvæ of *Lepidoptera* (fig. 189), commonly called "caterpillars," are vermiform in shape, normally composed of thirteen segments, the first of which forms a distinct horny head, with antennæ, jaws, and usually simple eyes. The mouth of the caterpillar, unlike that of the perfect insect, is formed for mastication. The labium, also, is provided with a tubular organ —the "spinneret"—which communicates with two internal glands, the functions of which are to furnish the silk, whereby the animal constructs its ordinary abode or spins its cocoon. The viscera are embedded in a largely developed fatty tissue (epiploön), which is absorbed by the pupa during its period of quiescence. The three segments behind the head correspond with the prothorax, mesothorax, and metathorax of the perfect insect, and each carries a pair of jointed walking-legs. Besides these thoracic legs, there is a variable number (generally five pairs) of soft fleshy legs, which are borne by the segments of the abdomen, and are known as "pro-legs." Each is usually furnished with a crown of several rows of small horny hooks, and they are never attached to the 4th, 5th, 10th, and 11th segments behind the head (*i.e*, to the 1st 2d, 7th, or 8th abdominal segments).

In the Diurnal *Lepidoptera*, or Butterflies proper (fig. 189), the antennæ are knobbed (hence the name of *Rhopalocera* often given to the group); the wings are usually held erect when the insect is in a state of repose; the larvæ have six thoracic legs, and ten pro-legs; and the pupæ are always naked, attached by the posterior extremity, or head downwards, and usually angular.

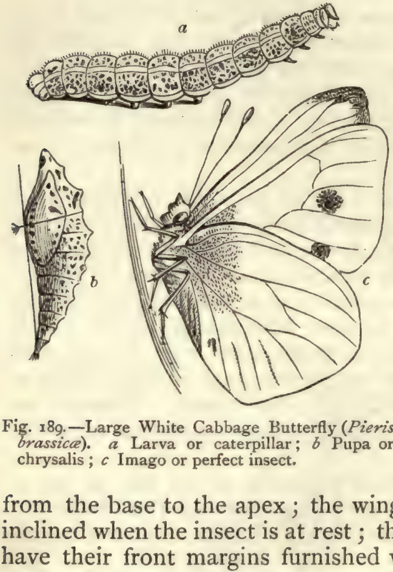

Fig. 189.—Large White Cabbage Butterfly (*Pieris brassicæ*). *a* Larva or caterpillar; *b* Pupa or chrysalis; *c* Imago or perfect insect.

In the Crepuscular *Lepidoptera*, including those forms which are active during the twilight, the antennæ are fusiform, or grow gradually thicker from the base to the apex; the wings are horizontal or a little inclined when the insect is at rest; the posterior wings generally have their front margins furnished with a rigid spine ("retinaculum") which is received into a hook on the under surface of the anterior wings; and the pupæ are never angular.

The Nocturnal *Lepidoptera* have the antennæ setaceous, or diminishing gradually from the base to the apex, often serrated or pectinated (fig. 190); the wings in repose are horizontal or deflexed, and the hind-wings are often furnished with a "retinaculum," as in the preceding section; the pupæ are mostly smooth, sometimes spiny, and often enclosed in a cocoon.

The two groups of the Crepuscular and Nocturnal *Lepidoptera* are often included in a single division, under the name of *Heterocera*. It is to be remembered that many members of the Nocturnal division of the order, though they would ordinarily be called Moths, are active during the day, and in this respect resemble the true Butterflies.

ORDER XI. HYMENOPTERA.—*Wings four, membranous, with* *few nervures; sometimes absent. Mouth always provided with biting-jaws or mandibles; the maxillæ and labium generally converted into a suctorial organ. Females having the extremity of the abdomen furnished with an ovipositor* (*terebra or aculeus*), *consisting generally of five or six pieces, of which the two outer form a protective sheath.* Besides the compound eyes, there are usually three ocelli placed on the top of the head. The antennæ are generally filiform or setaceous. The metamorphosis is complete, but the various parts of the pupa are visible through the delicate enclosing membrane. The larvæ are sometimes provided with feet, and live on vegetable food (as in the *Tenthredinidæ*, fig. 191); but they are mostly footless, without a distinct head, and fed by the adult.

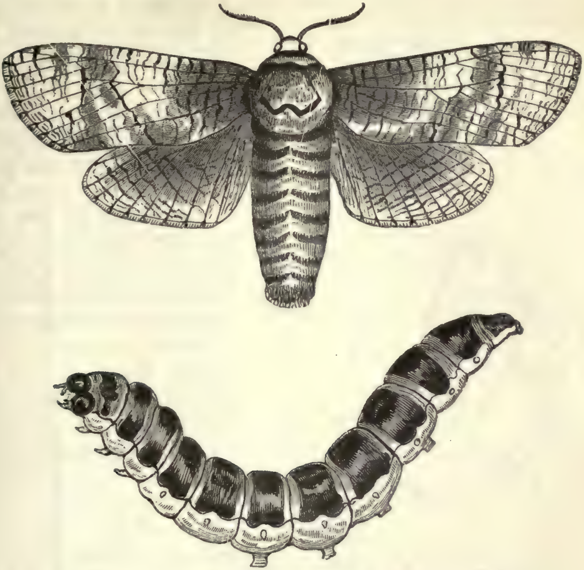

Fig. 190.—Goat-moth (*Cossus ligniperda*) and Caterpillar.

The *Hymenoptera* form a very extensive order, comprising the Bees, Wasps, Ants, Ichneumons, Saw-flies, &c. The ovipositor, which is characteristic of the females of this order, is very commonly modified so as to constitute a saw (*serra*), a boring organ (*terebra*), or a sting (*aculeus*).

As regards the principal groups of the *Hymenoptera*, the Saw-flies (*Tenthredinidæ* and *Siricidæ*) form a very natural section, which is often spoken of as that of the *Terebrantia*, as the females have the ovipositor converted into a saw or borer. The larvæ of the Saw-flies (fig. 191) feed upon vegetable matter, and have pro-legs. Another important group is that of the Gall-flies (*Cynipidæ*), all of which lay their eggs in the soft tissues of plants (generally the leaves). The resulting "galls" are due to the abnormal cell-growth excited locally in the plant by the irritation caused by the puncture of the mother's ovipositor in depositing the eggs. The larvæ are footless. In the allied group of the Ichneumons (*Ichneumonidæ*), the larvæ are also footless, and the eggs are deposited by the females in the larvæ or pupæ of other insects, upon whose tissues the young support themselves after hatching All the other *Hymenoptera* have the ovipositor of the female converted into a sting (not always the case in the Ants), and they may therefore be grouped together under the common title of *Aculeata*. The principal families included under this name are the Ants (*Formicidæ*), the Wasps (*Vespidæ*), the Hornets (*Crabronidæ*), the Bees (*Apidæ*), and the Bumble-bees (*Bombidæ*).

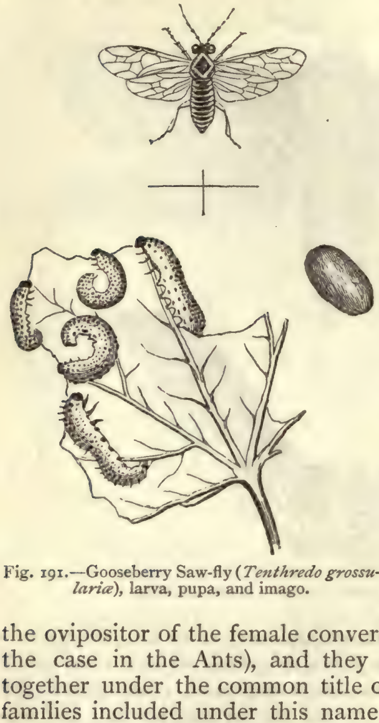

Fig. 191.—Gooseberry Saw-fly (*Tenthredo grossulariæ*), larva, pupa, and imago.

Amongst the *Hymenoptera* we find social communities, in many respects resembling those of the Termites, of which a description has already been given. The societies of Bees and Ants are well known, and merit a short description.

The social Bees, of which the common Honey-bee (*Apis mellifica*), is so familiar an example, form organised communities, consisting of three classes of individuals—the males, females, and neuters. As a rule, each community consists of a single female—"the queen"—and of the neuters, or "workers." The impregnation of the female is effected by the production of males, or "drones," during the summer. After impregnation has been effected, the drones, as being then useless, are destroyed by the workers. The eggs produced by the fecundated queen are mostly intended to give origin to neuters, to which end they are placed in the ordinary cells. The ova which are to give origin to females—the "queens" of future colonies—are placed in cells of a peculiar construction, and the larvæ are fed by the workers with a special food. The ova which are to produce males are likewise placed in cells, which are slightly larger than those allotted to the workers. It is asserted, however, that this is not the sole or true cause of the production of the males; but that the ova which are intended to produce drones are not fertilised by the female with the semen which she has stored up in her spermatheca, and are therefore produced by a process of parthenogenesis. That the males are produced parthenogenetically in some, at any rate, of the *Hymenoptera*, appears to have been placed beyond a reasonable doubt by the researches of Von Siebold. (See Introduction.)

In the Bumble-bees (*Bombidæ*), and in the Wasps (*Vespidæ*), we have societies essentially the same as in the Honey-bee. In a large community of Wasps, or "vespiary," there may be several hundred females, of which few survive the winter, and live to found fresh colonies next spring. The number of males is about equal to that of the females, but, unlike the drones of the Bees, the males work actively and defend the nest. As amongst the Bees, solitary species are not uncommon.

The Ants (*Formicidæ*) likewise form communities, consisting of males, females, and neuters (fig. 192). The males and females, as we have seen in the case of the Termites, are winged, and are produced in great numbers at a particular period of the year. They then quit the nest and pair, after which the males die. The females then lose their wings and fall to the ground, when they become the queens of fresh societies. In some Ants, as in the Termites, the neuters are divided into two classes—the workers and the soldiers—of which the former perform all the duties necessary for the preservation of the society except defending the nest, this being left to the soldiers. In other cases, as many as three distinct orders or "castes" of neuters may be present in the same nest.

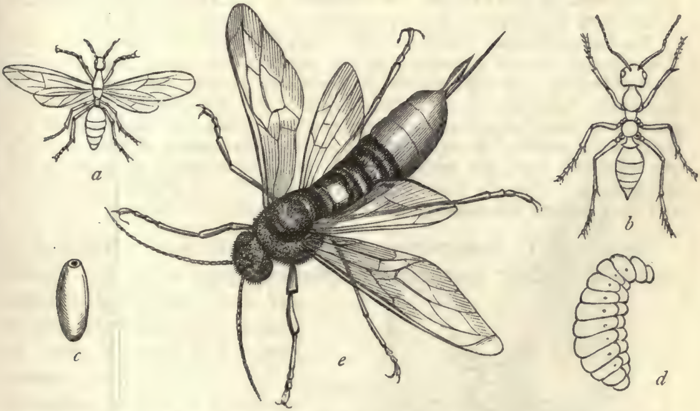

Fig. 192.—*a* Winged male of Ant; *b* Wingless worker of Ant; *c* Pupa of Ant; *d* Lavra of Ant, enlarged; *e* The Great Saw-fly (*Sirex gigas*).

Amongst the more singular of the habits and instincts of Ants two may be mentioned—the instinct of making slaves, and that of milking, so to speak, the little Plant-lice (*Aphides*). As regards the first of these, it is found that certain Ants possess the extraordinary instinct of capturing the pupæ of other species of Ants, and bringing them up as slaves. The relations between the masters and the slaves vary a good deal in different species. In the case of *Polyergus rufescens*, for instance, the masters are entirely dependent upon their slaves; the males and females do nothing except reproducing the species, and the neuters perform no other labour except that of capturing fresh slaves. The masters are in this case unable even to feed themselves, and their existence is maintained entirely by the devotion of the slaves. In *Formica sanguinea*, on the other hand, the number of slaves is much less, and both masters and slaves occupy themselves in performing most of the duties necessary for the community. The masters, however, go alone when on slave-making expeditions; and in case of a migration, the masters carry the slaves in their mouths.

A second singular fact in the history of Ants is found in the relations which subsist between them and the *Aphides*, or Plant-lice. The *Aphides* secrete, or rather excrete, a peculiar viscid and sweet liquid, by means of a gland which is situated towards the extremity of the abdomen, and communicates with the exterior by two tubular filaments. Ants are extremely fond of this excretion, and it is a well-established fact that the *Aphides* allow themselves to be *milked*, as it were, by the Ants. For this purpose the Ant touches and caresses the abdomen of the Aphis with its antennæ, whereupon the latter voluntarily exudes a drop of the coveted fluid.

The belief that our European Ants stored up grain for winter consumption, though generally asserted by the ancients, has been, until recently, discredited by scientific observers, upon the ground that our Ants are known to be carnivorous in their habits. Mr Moggridge has, however, recently shown that there are exceptions to this rule, and that some of the Ants of the south of Europe (such as some of the species of *Atta*) not only eat vegetable food, but really execute the feats imputed to them by the old writers. They do, namely, store up a provision of grain for the winter, and they prevent this from germinating by gnawing the radicle.

ORDER XII. STREPSIPTERA.—*Females without wings or feet, parasitic. Males possessing the posterior pair of wings, which are large, membranous, and folded longitudinally like a fan. The anterior pair of wings rudimentary, represented by a pair of singular twisted organs. Jaws rudimentary.*

The *Strepsiptera* constitute a small order, which includes certain parasites of minute size, found on Bees and other *Hymenoptera*. The female is a soft vermiform grub, without feet or wings, but with a horny head, which it protrudes from between the abdominal segments

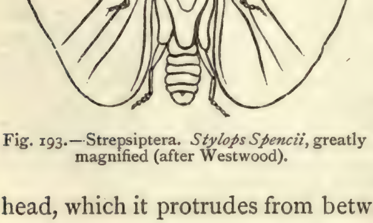
Fig. 193.—Strepsiptera. *Stylops Spencii*, greatly magnified (after Westwood).

of its host. The larvæ are active, and possess six feet; whilst the males (fig. 193) are winged, and fly about with great activity.

The *Strepsiptera* are now very generally regarded as an anomalous and degraded group of the *Coleoptera*.

ORDER XIII. COLEOPTERA.—*Mouth masticatory, furnished with an upper lip or labrum, two mandibles, two maxillæ, with maxillary palpi (generally four-jointed), and a movable lower lip or labium, with two jointed labial palpi. The four wings are usually present, and the anterior pair are not adapted for flight, but are hardened by chitine, so as to form protective cases (elytra) for the posterior wings* (fig. 194). *The inner margins of the elytra are generally straight, and when in contact they form a longitudinal suture. The posterior wings are membranous, and when not in use are folded transversely beneath the elytra.* (Amongst deviations from this state of parts may be mentioned the occasional absence or rudimentary condition of the hinder wings, the soldering together of the elytra, the soft and yielding condition of the elytra, or the absence of both elytra and wings.) The eyes are always compound, generally circular, oval, or reniform, but sometimes completely divided. The antennæ are extremely variable in form, generally of eleven joints, sometimes of fewer, rarely of twelve or more. The thorax is composed of a pro- meso- and meta-thorax, but when the elytra are closed, only the prothorax and a little plate ("scutellum") belonging to the mesothorax are visible.

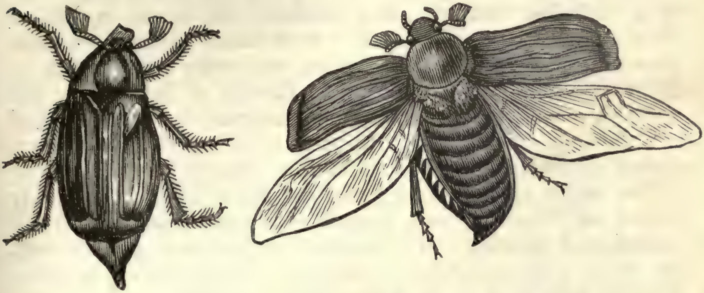

Fig. 194.—Coleoptera. Common Cockchafer (*Melolontha vulgaris*).

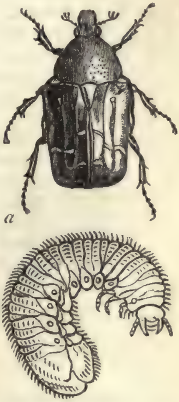

Fig. 195.—*a* Rose-chafer (*Cetonia aurata*) and larva.

The tarsus is generally composed of five joints, sometimes fewer, never more, and its last joint is usually furnished with two hooked claws.

The larvæ of *Coleoptera* are generally composed of thirteen segments, including the head. The body is generally soft and fleshy, the head horny, and the mouth adapted for mastication, the food being sometimes of an animal and sometimes of a vegetable nature. The antennæ are small, usually of three or four joints, with ocelli at their base. They have three pairs of legs attached to the thorax, and rarely anal pro-legs or fleshy tubercles; or they may be devoid of feet (as in the weevils). The pupa is sometimes enclosed in a cocoon, and is always quiescent; and the parts of the perfect insect are always distinctly recognisable in the pupa.

The order *Coleoptera* includes all those insects commonly known as "Beetles," and comprises an enormous number of genera and species. They are remarkable, as a general rule, for their hard polished integument, their glittering, often metallic colours, and their voracious habits.

The order *Coleoptera* was divided by Latreille into four sections, in accordance with the number of the joints in the tarsi; and though the resulting arrangement is not strictly natural, this classification is generally followed. The four sections founded by Latreille are:—

1. TRIMERA.—Tarsus three-jointed. *Ex.* Lady-birds (*Coccinellidæ*).
2. TETRAMERA.—Tarsus four-jointed. *Ex.* The Longicorn Beetles (*Longicornia*), the Weevils (*Rhynchophora*), &c.
3. HETEROMERA.—Tarsus of the two anterior pairs of legs five-jointed, of the posterior pair four-jointed. *Ex.* The Blister Beetles (*Cantharidæ*), and the great family of the *Tenebrionidæ*.
4. PENTAMERA.—Tarsus five-jointed in all the legs. *Ex.* Soldier-beetles (*Telephorus*), Glow-worm (*Lampyris*), the *Elateridæ* (the larvæ known as "wire-worms") the beautiful *Buprestidæ*, the great group of the Lamellicorn Beetles (such as the Stag-beetle, Cockchafer, Dung-beetle, &c.), the Burying beetles (*Necrophorus*), the Devil's-coach-horses (*Staphylinidæ*), the Water-beetles (*Hydrophilidæ* and *Dytiscidæ*), the Whirligigs (*Gyrinidæ*), the Ground-beetles (*Carabidæ*), and the Tiger-beetles (*Cicindelidæ*).

LITERATURE.

GENERAL WORKS.

1. "Glieder-füssler: Arthropoda," in 'Bronn's Klassen und Ordnungen des Thier-Reichs.' Gerstaecker.
2. "Règne Animal." Cuvier.
3. "Sur un nouveau rapprochement à établir entre les classes qui composent le règne animal." Cuvier. 'Annales du Muséum.' 1812.
4. "Histoire naturelle des animaux sans vertèbres." Lamarck. 1835-45.
5. "Handbuch der Zoologie." Carus und Gerstaecker. 1863.

CRUSTACEA.

6. Article "Crustacea," in 'Encyclopædia Britannica,' 9th ed. vol. vi. Henry Woodward. 1877.
7. Article "Crustacea." 'Todd's Encyclopædia of Anatomy and Physiology.' Milne-Edwards. 1835.
8. "Histoire Naturelle des Crustacés." Milne-Edwards. 1834-40.
9. "History of British Stalk-eyed Crustacea." Bell. 1853.
10. "History of British Sessile-eyed Crustacea." Spence Bate and J. O. Westwood. 1863.
11. "Report on the present state of our Knowledge of Crustacea." Spence Bate. 'Brit. Assoc. Rep.' 1875.
12. "Crustacea of the United States' Exploring Expedition." Dana. 1852-53.
13. "Facts and Arguments for Darwin." Fritz Müller. English translation of "Für Darwin" by W. S. Dallas. 1869.
14. "Monograph of the Cirripedia." Darwin. 'Ray Society.' "Lepadidæ," 1851. "Balanidæ," 1854.
15. "Fossil Lepadidæ of Britain." Darwin. 'Palæontographical Society.' 1851.
16. "Fossil Balanidæ of Britain." Darwin. 'Palæontographical Society.' 1854.
17. "On the Development of Lepas fascicularis and the 'Archizoea' of the Cirripedia." Von Willemoës-Suhm. 'Phil. Trans.' 1876.
18. "A Monograph of the Free and Semi-parasitic Copepoda of the British Islands." G. S. Brady. 'Ray Society.' 1878.
19. "Natural History of British Entomostraca." Baird. 'Ray Society.' 1850.
20. "Naturgeschichte der Daphniden." Leydig. 1860.
21. "Die frei-lebenden Copepoden," &c. Claus. 1863.
22. "Monograph of the Recent British Ostracoda." G. S. Brady. 'Trans. Linn. Soc.' 1866.
23. "Översigt af Norges marine Ostracoder." G. O. Sars. 1865.
24. "On the Anatomy and development of the American King Crab." Owen. 'Trans. Linn. Soc.' 1872.
25. "Development of Limulus polyphemus." A. S. Packard. 'Mem. Boston Soc. Nat. Hist.' 1871.
26. "Zur Embryologie und Morphologie des Limulus polyphemus." Dohrn. 'Jenaischen Zeitschr.' 1871.
27. "Recherches sur l'hist. nat. et Anat. des Limules." Van der Hoeven. 1838.
28. "On the Relation of the Xiphosura to the Eurypterida." Henry Woodward. 'Quart. Journ. Geol. Soc.' 1872.
29. "Monograph of the Fossil Merostomata." Henry Woodward. 'Palæontographical Society.' 1866-1872.
30. "Report on the Structure and Classification of Fossil Crustacea." Henry Woodward. 'Rep. Brit. Assoc.' 1871.
31. "Monograph of the British Trilobites." Salter. 'Palæontographical Society.' 1862-64.
32. "Monograph of Trilobites." Barrande. In 'Système Silurien de Bohême.' 1852.
33. "Organisation of Trilobites." Burmeister. 'Ray Society.' 1846.
34. "Histoire Naturelle des Crustacés fossiles." Brongniart and Desmarest. 1822.

35. “Catalogue of the British Fossil Crustacea.” Henry Woodward. 1877.
36. “Fossil Estheriæ.” Rupert Jones. ‘Palæontographical Society.’ 1862.
37. “British Tertiary Entomostraca.” Rupert Jones. ‘Palæontographical Society.’ 1856.
38. “On the Development of the Decapod Crustacea.” Spence Bate. ‘Phil. Trans.’ 1858.
39. “Malacostraca Podophthalma Britannica.” Leach. 1815-75. (Completed by G. B. Sowerby.)

ARACHNIDA.

40. Article “Arachnida.” Rev. O. P. Cambridge. ‘Encyclopædia Britannica,’ 9th ed. vol. ii. 1875.
41. “Guide to the Study of Insects.” Packard, 3d ed. 1872.
42. Article “Arachnida.” Audouin. ‘Todd’s Cyclopædia of Anatomy and Physiology.’ 1835.
43. “Bau und Entwickelungs-geschichte der Pentastomiden.” Leuckart.
44. “Studien an Acariden.” Claparède.
45. “Mémoire sur les Tardigrades.” Doyère. ‘Ann. Sciences Nat.’ 1840.
46. “Recherches sur l’organisation et la développement des Linguatules.’ Van Beneden. ‘Nouv. Mém. de l’Acad. de Belg.’ 1849.
47. “Beiträge zur Anatomie der Milben.” Pagenstecher. 1860.
48. “Ueber Entwickelung und Bau der Pycnogoniden.” Dohrn. In ‘Ueber Bau und Entwickelung der Arthropoden.’ 1879.
49. “Monograph of the British Species of Phalangiidæ.” Meade. ‘Ann. Nat. Hist.’ 1855.
50. “Die Arachniden.” Koch. 1831-48.
51. “Uebersicht des Arachniden Systems.” Koch. 1850.
52. “Embryologie des Scorpions.” Metschnikoff. 1870.
53. “Histoire Naturelle des Insectes Aptères.” Walckenaer. 1837.
54. “Histoire des Araignées. Simon. 1864.
55. “On the Genera of European Spiders.” Thorell. 1870.
56. “History of the Spiders of Great Britain and Ireland.” Blackwall. ‘Ray Society.’ 1861-64.
57. “De Generatione Aranearum in Ovo.” Herold. 1824.
58. “Ueber den innern Bau der Arachniden.” Treviranus. 1812.
59. “Recherches sur l’évolution des Araignées.” Claparède. 1862.
60. “Trap-door Spiders and Harvesting Ants.” Moggridge. 1873.

MYRIAPODA.

61. “Guide to the Study of Insects.” Packard. 1872.
62. “On the Organs of Reproduction and the Development of the Myriapoda.” Newport. ‘Phil. Trans.’ 1841.
63. Article “Myriapoda.” Rymer Jones. ‘Todd’s Cyclopædia of Anat. and Physiology.’ 1839-47.
64. “On Pauropus, a new Type of Centipede.” Sir John Lubbock. ‘Trans. Linn. Soc.’ 1868.
65. “Ueber den Bau von Peripatus Edwardsii.” Grube. ‘Archiv für Anat.’ 1853.
66. “On the Structure and Development of Peripatus Capensis.” H. N. Moseley. ‘Proc. Roy. Soc.’ 1874; and ‘Ann. Nat. Hist.’ 1874.

67. "On Peripatus Novo-Zelandiæ." Capt. F. W. Hutton. 'Ann. Nat. Hist.' 1876.
68. "Embryologie der doppelt-füssigen Myriapoden. Metschnikoff. 'Siebold und Kölliker's Zeitschrift.' 1874.
69. "Embryologisches über Geophilus." Metschnikoff. 'Siebold und Kölliker's Zeitschrift.' 1875.

INSECTA.

70. "Introduction to the Modern Classification of Insects." Westwood. 1839-40.
71. "Introduction to Entomology." Kirby and Spence. 1828.
72. "Handbuch der Entomologie." Burmeister. 1832-47.
73. "Guide to the Study of Insects." Packard. 1872.
74. Article "Insecta." Newport. 'Todd's Cyclopædia of Anatomy and Physiology.' 1836-39.
75. "Mémoires pour servir à l'histoire des Insectes." De Geer. 1752-78.
76. "Mémoires pour servir à l'histoire des Insectes." Reaumur. 1734-42.
77. "Systema Entomologiæ." Fabricius. 1775.
78. "Histoire naturelle des Crustacés et des Insectes." Latreille. 1802-05.
79. "British Entomology." Curtis.
80. "British Butterflies." Humphrey and Westwood. 1841.
81. "British Moths." Humphrey. 1843-45.
82. "British Moths and Butterflies. Newman. 1874.
83. "Insects of North America." Say. (Ed. by Le Conte.) 1869.
84. "Origin and Metamorphoses of Insects." Sir John Lubbock. 1874.
85. "On the Thysanura." Sir John Lubbock. 'Trans. Linn. Soc.' 1862, 1867, 1869.
86. "Monograph of the Collembola." Sir John Lubbock. 'Ray Society.'
87. "Transformations of Insects." Martin Duncan. 1875.

MOLLUSCA.

CHAPTER XL.

SUB-KINGDOM MOLLUSCA.

SUB-KINGDOM MOLLUSCA.—The *Mollusca* may be defined as including soft-bodied, unsegmented animals, which are usually provided with an exoskeleton. The intestinal canal is bounded by its own proper walls, and is completely shut off from the perivisceral cavity. The alimentary canal is situated between the hæmal system, which lies dorsally, and the neural system, which is situated towards the ventral aspect of the body. The nervous system (fig. 196) in its highest development consists of three principal ganglia, which are reduced to one in the lower forms. Usually there is a distinct propulsive organ by which the circulation is carried on, but this is occasionally absent. Distinct respiratory organs may or may not be present. Reproduction is sexual, though gemmation is also occasionally superadded. The higher *Mollusca* are all simple animals, but many of the lower forms are capable of forming colonies by continuous gemmation.

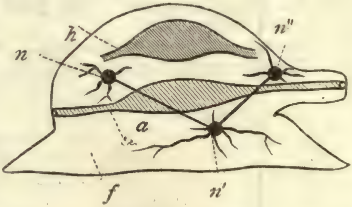

Fig. 196.—Diagram of a Mollusc. *a* Alimentary canal; *h* Heart; *f* Foot; *n* Cerebral ganglion; *n′* Pedal ganglion; *n″* Parieto-splanchnic ganglion.

The digestive system in all the *Mollusca* consists of a mouth, gullet, stomach, intestine, and anus—though in some of the *Brachiopoda*, and in a few other forms, the intestine ends cæcally. In some the mouth is surrounded by ciliated tentacles (*Polyzoa*, fig. 199); in others it is furnished with two ciliated arms (*Brachiopoda*, fig. 204); in the bivalves (*Lamellibranchiata*) it is mostly furnished with four membranous processes or palpi (fig. 208); in others it is provided with a complicated apparatus of teeth (*Gasteropoda*, fig. 213, and *Pteropoda*); and, lastly, the *Cephalopoda* have, in addition, horny or calcareous mandibles, forming a kind of beak. Well-developed salivary glands are usually present; the liver in the higher forms is of large size, and pours its secretion either into the stomach or into the commencement of the intestine; and a renal organ has been detected in most of the *Mollusca* proper. There is no distinct absorbent system, but the products of digestion pass by exosmose into the general abdominal cavity, and thence into the larger veins.

The blood is colourless, or nearly so. In the *Polyzoa* the circulation is carried on by ciliary action, and there is no distinct propulsive organ, or definite course of the circulating fluid. In the *Tunicata* the heart is a simple tube, open at both ends, and the course of the circulation is periodically reversed. In the *Brachiopoda* the course of the circulation is not definitely ascertained, and it is doubtful if a true heart is present in all. In the higher *Mollusca* a distinct heart is always present, and consists of an auricle which receives the aerated blood from the breathing-organ, and a muscular ventricle which propels it through the systemic vessels. That a system of capillaries in many cases intervenes between the arteries and veins, appears from recent researches to be probable. In all cases the heart of the *Mollusca* is systemic, distributing the aerated blood to the body; and in no case is it respiratory, propelling the non-aerated blood to the breathing-organ.

In the *Polyzoa* there is no differentiated respiratory organ, and the function of respiration is discharged mainly by the oral crown of ciliated tentacles. In the *Tunicata* respiration is effected by means of the pharyngeal or branchial sac; and in the *Brachiopoda* by the oral arms, and possibly, to some extent, by an "atrial" or "water-vascular" system, furnished with contractile dilatations. In the higher *Mollusca* a distinct breathing-organ is always present, a portion of the mantle being specialised for this purpose. In the *Lamellibranchiata*, and the branchiate *Gasteropoda*, the breathing-organs are in the form of lamellar and pectinate gills; and the same is the case with the *Cephalopoda*. In the pulmonate *Gasteropoda*, in which respiration is aerial, a pulmonary sac or air-chamber is produced by the folding of a portion of the mantle, over the interior of which the pulmonary vessels are distributed. The chamber thus formed communicates with the exterior by a round aperture, which can be opened or closed at will; and the renovation of the effete air within the sac appears to be effected mainly or entirely by simple diffusion.

The nervous system varies considerably in its development. In the *Polyzoa*, *Tunicata*, and *Brachiopoda*—which collectively constitute the *Molluscoida*—the nervous system consists of a single ganglion, or of a principal pair with accessory ganglia, placed between the oral and anal apertures. The true Molluscan type (fig. 196), however, of nervous system is constituted by the presence of three pairs of ganglia, connected with one another by commissures, but distributed in a characteristically scattered manner (heterogangliate type). One of these ganglia is situated above the œsophagus, and is called the "supra-œsophageal" or "cerebral" ganglion. A second is placed below the œsophagus, and is termed the "infra-œsophageal" or "pedal" ganglion (from its supplying the nerves to the "foot"). The third pair is the most persistent, and is termed the "branchial" or "parieto-splanchnic" ganglion. In many of the higher *Mollusca*, however, the cerebral and pedal ganglia are fused in an œsophageal ring.

Organs of sight exist in some of the lower, and in the majority of the higher, *Mollusca*. In the *Cephalopoda*, and in some of the *Gasteropoda* (*e.g.*, *Strombidæ*), the eyes are of a very high type of organisation. In the *Lamellibranchiata* the adults are either destitute of organs of vision, or possess numerous simple eyes ("ocelli") placed along the margins of the mantle-lobes. Similar ocelli are also found in some of the *Tunicata*, placed between the oral tentacles. Organs of hearing ("otocysts") exist in the more highly organised *Mollusca*, especially in the *Gasteropoda* and *Cephalopoda*, and supposed olfactory organs occur in some of the latter.

Reproduction amongst the *Mollusca* is almost invariably sexual, but it is by continuous gemmation that the colonies of the *Polyzoa*, and the social and compound *Tunicata*, are produced, and the "statoblasts" of the former offer a good example of non-sexual reproduction. The sexes may be distinct, or are in many cases united in the same individual. In many forms the ova are arranged in rows, so as to form a strap or ribbon-shaped structure, termed the "nidamental ribbon." There is generally a distinct metamorphosis in development.

As implied by their scientific name, the *Mollusca* are mostly soft-bodied animals; but their popular name of "Shell-fish" expresses the fact, that the presence of a shell, protecting the soft body, is likewise a very characteristic feature in the subkingdom. At the same time, a shell is not universally present, and many of the *Mollusca* are either permanently naked, or possess nothing that would be ordinarily looked upon as a shell. When there is either no shell at all, or merely a rudimentary shell enclosed in the mantle, the Mollusc is said to be "naked." The shell of the "testaceous" *Mollusca* is very closely related to the respiratory organs; "indeed it may be regarded as a *pneumoskeleton*, being essentially a calcified portion of the mantle, of which the breathing-organ is at most a specialised part. . . . In its most reduced form the shell is only a hollow cone or plate, protecting the breathing-organ and heart, as in *Limax*, *Testacella*, and *Carinaria*. Its peculiar features always relate to the condition of the breathing-organ, and in *Terebratula* and *Pelonaia* it becomes identified with the gill. In the *Nudibranchs* the vascular mantle performs, wholly or in part, the respiratory office. In the *Cephalopods* the shell becomes complicated by the addition of a distinct, internal, chambered portion (*phragmacone*), which is properly a *visceral* skeleton" (Woodward). In a great many of the *Mollusca* proper the shell consists of but a single piece, and they are called "univalves." In many others the shell consists of two separate plates or "valves," and these are called "bivalves." In others, again, as in the *Chiton*, the shell consists of more than two pieces, and is said to be "multivalve." Most, however, of the multivalve shells of older writers are in reality referable to the *Cirripedia*.

All the testaceous *Mollusca* (except the Argonaut), and most of the "naked" forms, acquire a rudimentary shell before their liberation from the ovum. In the latter this rudimentary shell is cast off as the embryo grows, but in the former it becomes the "nucleus" of the adult shell. In the bivalves the embryonic shell or "nucleus" is situated at the beak or "umbo" of each valve, and is often very unlike the remainder of the shell.

In composition the shell of the *Mollusca* consists of carbonate of lime—usually having the atomic arrangement of calcite—with a small proportion of animal matter. In the *Pholadidæ*, however, the calcareous matter exists in the allotropic condition of arragonite, which is very much harder than calcite; and there are many Gasteropods in which the shell is similarly composed of arragonite. As regards their texture, three principal varieties of shells may be distinguished—viz., the "porcellanous," the "nacreous," and the "fibrous." In the "nacreous" or pearly shells, as seen in "mother-of-pearl," the shell has a peculiar lustre, due to the minute undulations of the edges of alternate layers of carbonate of lime and membrane. The "fibrous" shells are composed of successive layers of prismatic cells. The "porcellanous" shell has a more complicated structure, and is composed of three layers or strata, each of which is made up of very numerous plates, "like cards placed on edge." The direction in which the vertical plates are placed, is sometimes transverse in the central layer, and lengthwise in the two others; or longitudinal in the middle, and transverse in the outer and inner strata.

All living shells have an outer layer of animal matter, which is known as the "epidermis," or "periostracum." This is sometimes of extreme tenuity, but is sometimes very thick, the latter being especially the case with those shells which are found in fresh water.

In many of the spiral univalves, as the animal grows it withdraws itself from the upper portion of the shell, often partitioning off the space thus left vacant. In many instances the portion thus abandoned falls off, and the shell becomes "truncated," or "decollated;" this being the normal condition in fully-grown examples of some shells.

In the great majority of univalves the shell is coiled into a spiral, the direction of which is right-handed, but in some cases the spiral is left-handed, and the shell is said to be "reversed," or "sinistral." The reversed shell may occur as the normal condition of the species, or it may occur simply as a variety of a form which is normally right-handed, or "dextral."

The sub-kingdom *Mollusca* is divided into two great divisions, termed respectively the *Molluscoida*, and the *Mollusca proper*. In the former of these the nervous system consists of a single ganglion or principal pair of ganglia, and there is either no circulatory organ or an imperfect heart. In the latter the nervous system consists of three principal pairs of ganglia, and there is a well-developed heart, consisting of at least two chambers.

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MOLLUSCOIDA.

CHAPTER XLI.

POLYZOA. — Bryozoa

DIVISION A. MOLLUSCOIDA.—*Nervous system consisting of a single ganglion, or of a principal pair with accessory ganglia; no distinct organ of the circulation, or an imperfect heart.*

This division includes three classes—viz., the *Polyzoa*, the *Tunicata*, and the *Brachiopoda*.

CLASS I. POLYZOA (*Bryozoa*).—The members of this class are defined as follows:—"*Alimentary canal suspended in a double-walled sac, from which it may be partially protruded by a process of evagination, and into which it may be again retracted by invagination. Mouth surrounded by a circle or crescent of hollow, ciliated tentacles; animals always forming composite colonies*" (Allman).

All the *Polyzoa* live in an associated form in colonies or "polyzoaria," which are sometimes foliaceous (fig. 197), sometimes branched and plant-like, sometimes encrusting, and very rarely are free. Each "polyzoarium" consists of an assemblage of distinct but similar zoöids arising by continuous gemmation from a single primordial individual. The colonies thus produced are in very many respects closely similar to those of many of the Hydroid Polypes, with which, indeed, the *Polyzoa* were for a long time classed. The "polyzoarium," however, of a *Polyzoön* differs from the polypidom of a composite Hydroid in the *general* fact that the separate cells of the former do not communicate with one another otherwise than by the continuity of the external integument; whereas the zoöids of the latter are united by an organic connecting medium, or "cœnosarc," from which they take their origin.

In one group of the *Polyzoa*—viz., the *Ctenostomata* (including *Vesicularia* and its allies), the cells arise from a common stalk, and are thus placed in communication with one another;

but this hardly affects the general value of the distinction above spoken of.

The homomorphism, however, which subsists between the *Polyzoa* and the *Hydroida*, is shown most decisively not to be a true affinity, when the structure of the individual zoöids is examined. The polypite of a Hydroid Zoophyte, as we have already seen, possesses no alimentary canal distinct from the general cavity of the body; there are no traces of a nervous system, and the reproductive organs are in the form of external processes of the body-wall. In the zoöid of all the *Polyzoa* (fig. 198, 2), on the other hand, there is a distinct alimentary canal, completely shut off from the somatic cavity; a nervous system is present, and the reproductive organs are contained within the body.

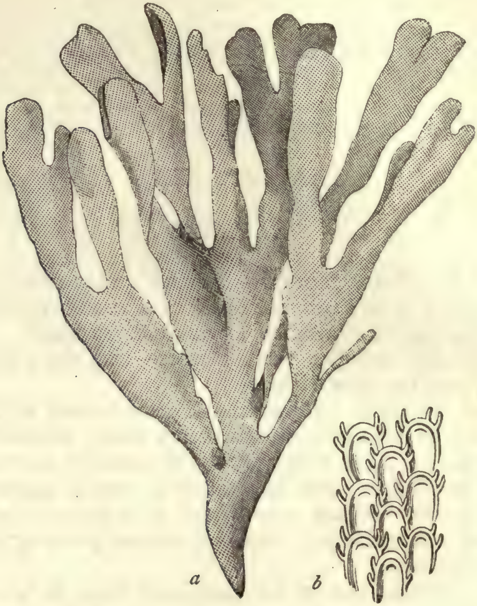

Fig. 197.—*Flustra foliacea*, one of the Sea-mats. *a* Portion of the colony, natural size; *b* A fragment magnified, to show the cells in which the separate polypides are contained.

In the *Polyzoa*, the entire colony—or its entire dermal system—is called the "polyzoarium" or "cœnœcium;" the separate zoöids are called "polypides;" and the little chambers in which each is contained are called the "cells," or "zooœcia."

It will be seen, therefore, that the term *polypite* is restricted to the zoöid of a compound *Hydrozoön*, or to the entire hydrosoma of a simple member of the class. The term *polype* is applied to a simple *Actinozoön*, or to the zoöids of a compound actinosoma. Lastly, the term *polypide* is exclusively employed to designate the zoöid of one of the *Polyzoa*.

The construction of a typical polypide of a *Polyzoön* is thus described by Professor Allman (fig. 198, 2):—

"Let us imagine an alimentary canal, consisting of œsophagus, stomach, and intestine, to be furnished at its origin with long ciliated tentacula, and to have a single nervous ganglion placed upon one side of the œsophagus. Let us now suppose this canal to be bent back upon itself towards the side of the ganglion, so as to approximate the termination to the origin. Let us further imagine the digestive tube thus constituted to be suspended in a fluid contained in a membranous sac with two openings, one for the mouth and the other for the vent, the tentacula alone being external to the sac. Let us still further suppose the alimentary tube, by means of a system of muscles, to admit of being retracted or pro-

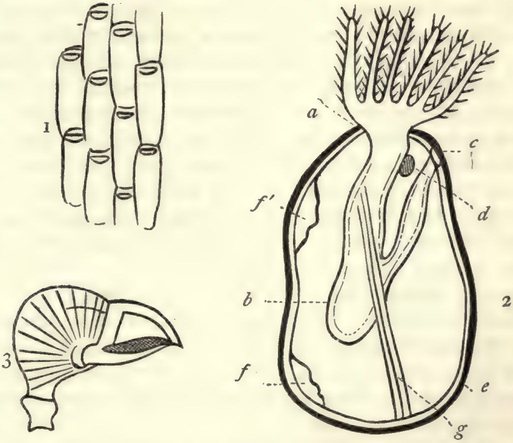

Fig. 198.—Morphology of Polyzoa. 1. Portion of the cœnœcium of *Flustra truncata*, magnified. 2. Diagram of a Polyzoön (after Allman): *a* Region of the mouth surrounded by tentacles; *b* Alimentary canal; *c* Anus; *d* Nervous ganglion; *e* Investing sac (ectocyst); *f* Testis; *f′* Ovary; *g* Retractor muscle. 3. Bird's-head process, or "avicularium," of a Polyzoön.

truded according to the will of the animal; the retraction being accompanied by an invagination of the sac, so as partially or entirely to include the oral tentacles within it; and if to these characters we add the presence of true sexual organs in the form of ovary and testis, occupying some portion of the interior of the sac, and the negative character of the absence of all vestige of a heart, we shall have, perhaps, as correct an idea—apart from all considerations of homology or derivation from an archetype—as can be conveyed of the essential structure of a *Polyzoön* in its simplest and most generalised condition.

"To give, however, more actuality to our ideal *Polyzoön*, we may bear in mind that the immediately investing sac has the power, in almost every case, of secreting from its external surface a secondary investment, of very various constitution in the different groups; and we may, moreover, conceive of the entire animal with its digestive tube, tentacula, ganglion, muscles, generative organs, circumambient fluid, and investing sacs, repeating itself by gemmation, and thus producing one or more precisely similar systems holding a definite position relatively to one another, while all continue organically united, and we shall then have the actual condition presented by the *Polyzoa* in their fully-developed state."

The vast majority of the *Polyzoa* are fixed, but this is not universally the case. Thus the singular fresh-water *Cristatella* is free and locomotive, creeping about by means of a flattened discoid base, not unlike the foot of the *Gasteropoda;* and the polyzoary seems to have been unattached in a few other forms (*Selenaria*, *Cupularia*, &c.)

The two fundamental structures of the "cœnœcium" of a *Polyzoön*—viz., the immediately investing sac, and its secondary investment—are sometimes termed the "endoderm" and "ectoderm;" but as these terms are employed in describing the *Hydrozoa*, it is better to make use of the terms "endocyst" and "ectocyst," proposed by Dr Allman.

The "ectocyst," or external investment of the cœnœcium, is usually a brown, pergamentaceous, probably chitinous, but often highly calcareous, membrane; and it is by the ectocyst that the "cells" are formed. In *Cristatella*, alone of the *Polyzoa*, there is no ectocyst; and in *Lophopus* (fig. 199, 3) and in the curious *Pectinatella* the ectocyst is gelatinous in its consistence. In many cases the ectocyst is provided with singular appendages, supposed to be weapons of offence and defence, or organs of prehension, termed "avicularia" (fig. 198, 3) and "vibracula." The avicularia, or "bird's-head processes," differ a good deal in shape, but consist essentially of "a movable mandible and a cup furnished with a horny beak, with which the point of the mandible is capable of being brought into apposition" (Busk). In shape the avicularia often closely resemble the head of a bird, and they are in many respects comparable with the "pedicellariæ" of the *Echinodermata*, keeping up a constant snapping movement, which continues long after the death of the general colony. In the "vibracula," the place of the mandible of the avicularium is taken by a bristle, or seta, which is capable of extensive movement. In many cases the cells are also furnished with globular sacs or pouches ("ovicells" or "oöcysts"), appended to them, and serving as marsupial pouches for the ova. Ovicells are only known in the marine *Polyzoa*, and the ova are liberated by their ultimate rupture.

It is generally believed that the avicularia, vibracula, and ovicells are really undeveloped polypides or modified zoöids. Good authorities also believe that the "cells" or "zoœcia" themselves are not to be regarded as mere skeletal structures, but that they have a life independent of that of their contained polypides, and that they can continue to live and produce new polypides after the death of the latter. They are regarded, in fact, as separate zooids.

The endocyst is always soft, contractile, and membranous; and, according to Sars, is wanting in *Rhabdopleura*. It lines the interior of the cells formed by the ectocyst, and is reflected backwards at the mouth of the cell, so as to be invaginated, or inverted into itself; and it finally terminates by being attached to the base of the circlet of tentacles. This invagination of the endocyst is more or less permanently present in all the fresh-water *Polyzoa*. The epithelium lining the inner surface of the endocyst is furnished with vibratile cilia.

The mouth of each polypide is surrounded by a crown of tubular, non-retractile tentacles, which have their sides ciliated, and are arranged sometimes in a circle and sometimes in a crescent. In the fresh-water *Polyzoa* the tentacles are united towards their bases by a funnel-shaped membrane, known as the "calyx." The tentacles are borne on a kind of disc, or stage, which is termed by Professor Allman the "lophophore." In the majority of *Polyzoa*—including almost all the marine species—the lophophore is circular (fig. 199, 2); but in most of the fresh-water forms it has its neural side extended into two long arms, so that the entire lophophore becomes crescentic or "horse-shoe-shaped" (fig. 199, 3); hence this section is sometimes collectively termed the "Hippocrepian" *Polyzoa*.

In all, or almost all, the *Polyzoa* in which this crescentic condition of the lophophore exists, there is also a singular valve-like organ which, springing from the anal side of the lophophore, arches over the mouth, and is termed the "epistome." The only marine forms in which the lophophore is bilateral are *Pedicellina* and *Rhabdopleura;* the only fresh-water species in which the lophophore is orbicular are *Paludicella* and *Urnatella.*

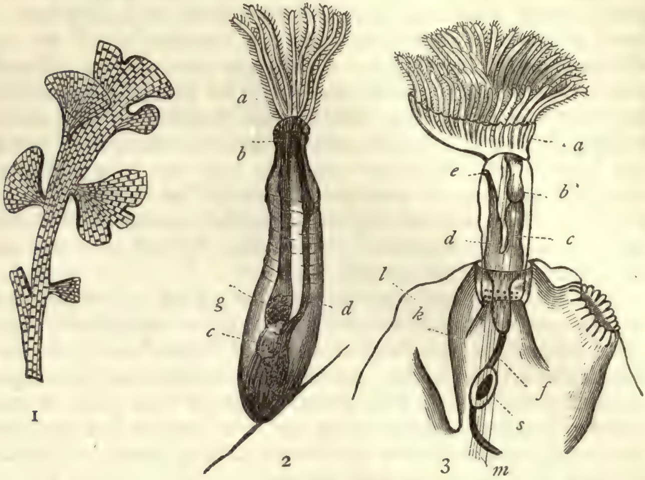

Fig. 199.—1. Fragment of *Flustra truncata*, one of the Sea-mats, natural size. 2. A single polypide of *Valkeria*, magnified, showing the orbicular crown of tentacles. 3. A polypide of *Lophopus crystallinus*, a fresh-water Polyzoön, highly magnified, showing the horse-shoe-shaped crown of tentacles. *a* Tentacular crown; *b* Gullet; *c* Stomach; *d* Intestine; *e* Anus; *g* Gizzard; *k* Endocyst; *l* Ectocyst; *f* Funiculus.

The mouth conducts by an œsophagus into a dilated stomach. In some cases a pharnyx may be present, and in others there is in front of the stomach a muscular proventriculus, or gizzard. From the stomach proceeds the intestine, which shortly turns forward to open by a distinct anus close to the mouth. As the nervous ganglion is situated on that side of the mouth towards which the intestine turns in order to reach its termination, the intestine is said to have a "neural flexure;" and this relation is constant throughout the entire class.

Respiration in the *Polyzoa* appears to be carried on by the ciliated tentacles, and by the "perigastric space," which is filled with a clear fluid, containing solid particles in suspension. A kind of circulation is kept up in this "perigastric fluid" by means of the cilia lining the inner surface of the endocyst. Beyond this there is nothing that could be called a circulation, and there are no distinct circulatory organs of any kind.

The nervous system in all the *Polyzoa* consists of a single small ganglion (fig. 198, 2), placed upon one side of the œsophagus, between it and the anal aperture, and apparently really of a double nature. Besides the single ganglion which belongs to each polypide, there is also in some of the *Polyzoa*, a "colonial nervous system;" that is to say, there is a well-developed nervous system, which unites together the various zoöids composing the colony, and brings them into relation with one another. It is probably in virtue of this system that the *avicularia* are enabled to continue their movements and retain their irritability after the death of the polypides; but high authorities deny that the so-called "colonial nerve-system" is really of a nervous nature at all.

The muscular system is well developed, and consists of various muscular bands, with special functions attaching to each. The most important fasciculi are the retractor muscles (fig. 198, 2, *g*), which retract the upper portion of the polypide within the cell. These muscles arise from the inner surface of the endocyst near the bottom of the cell, and are inserted into the upper part of the œsophagus. The polypide, when retracted, is again exserted, chiefly by the action of the "parietal muscles," which are in the form of circular bundles running transversely round the cell.

As far as is known, all the *Polyzoa* are hermaphrodite, each polypide containing an ovary and testis (fig. 198, 2). The ovary is situated near the summit of the cell, and is attached to the inner surface of the endocyst. The testis is situated at the bottom of the cell, and a curious cylindrical appendage, called the "funiculus," usually passes from it to the fundus of the stomach. There are no efferent ducts to the reproductive organs; and the products of generation—*i.e.*, the spermatozoa and ova—are discharged into the perigastric space, where fecundation takes place; and the impregnated ova escape by special openings in the body-wall, by dehiscence of the cell, or in some manner not as yet thoroughly understood.

As already mentioned, continuous gemmation occurs in all the *Polyzoa*, the fresh zoöids thus produced remaining attached to the organism from which they were budded forth, and thus giving rise to a compound growth.

A form of discontinuous gemmation, however, occurs in many of the Polyzoa, in which certain singular bodies, called "statoblasts," are developed in the interior of the polypide. The statoblasts are found in certain seasons lying loose in the perigastric cavity. In form "they may be generally described as lenticular bodies, varying, according to the species, from an orbicular to an elongated-oval figure, and enclosed in a horny shell, which consists of two concavo-convex discs united by their margins, where they are further strengthened by a ring which runs round the entire margin, and is of different structure from the discs. . . . When the statoblasts are placed under circumstances favouring their development, they open by the separation from one another of the two faces, and there then escapes from them a young *Polyzoön*, already in an advanced stage of development, and in all essential respects resembling the adult individual in whose cell the statoblasts were produced" (Allman). The statoblasts are formed as buds upon the "funiculus"—the cord already alluded to as extending from the testis to the stomach—upon which they may usually be seen in different stages of growth. They do not appear to be set free from the perigastric space prior to the death of the adult, and when liberated they are enabled to float near the surface of the water, in consequence of the cells of the marginal ring, or "annulus," being spongy and filled with air. They must be looked upon as "*gemmæ* peculiarly encysted, and destined to remain for a period in a quiescent or pupa-like state" (Allman).

As regards the development of the *Polyzoa*, the embryo upon its emergence from the ovum presents itself as a ciliated, free-swimming, sac-like body, from which the polypide is subsequently produced by a process of gemmation. In the singular *Rhabdopleura* the primitive bud is enclosed between two fleshy lobes or valve-like plates, attached along their dorsal margin, and giving exit in front to the rudimentary lophophore. As the development proceeds, these plates cease to keep pace in their growth with the rest of the bud; till ultimately they appear as a peculiar shield-like organ on the hæmal side of the lophophore. These lobes have been compared by Dr Allman with the mantle-lobes of the *Lamellibranchiata;* and according to the most recent researches, the whole shield-like organ is a specially modified zoöid, and in no way corresponds with the "epistome" of the *Phylactolæmata.*

DIVISIONS OF THE POLYZOA.—According to the classification proposed by Nitsche, and now generally adopted, the *Polyzoa* are divided into the two primary sections of the *Entoprocta* and the *Ectoprocta*, to which a third must be added, in accordance with the views of Dr Allman, under the name of *Aspidophora*, for the reception of the anomalous *Rhabdopleura*. The following are the principal groups of the *Polyzoa* :—

A. ECTOPROCTA.

Mouth within the circle of tentacles; anus dorsal and outside the tentacular circle; lophophore crescentic or circular.

Sub-order I. *Phylactolæmata.*
" " II. *Gymnolæmata.*

B. ENTOPROCTA.

Mouth and anus both within the circle of tentacles; lophophore horseshoe-shaped. Tentacles solid and non-retractile, filled, like the body-cavity, with parenchyma. Ectocyst not calcified. This division includes the marine *Pedicellina* and *Loxosoma*, and the fresh-water *Urnatella*. *Loxosoma* is semiparasitic, and is attached to the bodies of Gephyreans and other marine animals.

C. ASPIDOPHORA.

This division includes only the singular marine genus *Rhabdopleura*, in which the lophophore is crescentic, and carries a discontinuous series of tentacles; the mouth is lateral rather than terminal; a special shield-like organ is attached to the body of the lophophore, between the mouth and the anus; the cœnœcium is chitinous and tubular, and is supported by a correspondingly divided chitinous rod, attached superiorly to a fleshy contractile cord, which is in turn connected with the body of the polypites; and, lastly, the endocyst and tentacular sheath are wanting.

Of the above divisions of the *Polyzoa*, the two most important groups are those of the *Phylactolæmata* and *Gymnolæmata*. In the former of these are included almost all the fresh-water *Polyzoa*, and the lophophore is bilateral and horse-shoe-shaped in all except *Fredericella*. The division of the *Gymnolæmata*, on the other hand, includes the fresh-water genera *Paludicella* and *Urnatella*, and the vast majority of the marine *Polyzoa*. Of these latter, the sub-order of the *Cheilostomata* is the most important, as embracing the greater number of the common forms. In these, the opening of the cell is sub-terminal, and is generally closed by a movable lip or shutter. On the other hand, in the sub-order *Cyclostomata*, the cells are tubular, the orifices terminal, of the same diameter as the cell itself, and without any movable apparatus for closure. Lastly, in the singular group of the *Ctenostomata* (including *Vesicularia*, *Alcyonidium*, and *Valkeria*), the cells arise from a common tube, and their mouths are terminal, and furnished with a setose fringe for their closure.

AFFINITIES OF THE POLYZOA.—By many zoologists the *Polyzoa* are now regarded as being an anomalous class of Worms, closely related to the true *Annelides*. That there are points of relationship between these apparently diverse groups cannot be doubted; but these do not seem sufficient to outweigh the points of divergence—such, for example, as the absence of segmentation in the former, and the totally different form of the nervous system. The *Polyzoa* have also striking affinities with the *Brachiopoda* and *Tunicata*, and even with some of the *Mollusca* proper; and it has not, therefore, appeared advisable to remove them to the division of the *Anarthropoda*.

DISTRIBUTION OF POLYZOA IN SPACE.—The *Polyzoa*, like all the *Molluscoida*, are exclusively aquatic in their habits, but unlike the remaining two classes, they are not exclusively confined to the sea. The marine *Polyzoa* are of almost universal occurrence in all seas. The fresh-water *Polyzoa*, however, not only differ materially from their marine brethren in structure, but appear to have a much more limited range, being, as far as is yet known, principally characteristic of the north temperate zone. Britain can claim the great majority of the described species of fresh-water *Polyzoa*, but this is probably due to the more careful scrutiny to which this country has been subjected. Fresh-water *Polyzoa* have also been found in the southern hemisphere, in Australia and India.

Distribution of Polyzoa in Time.—The *Polyzoa* have left abundant traces of their past existence in the stratified series, commencing in the Lower Silurian rocks and extending up to the present day. The *Oldhamia* of the Cambrian rocks of Ireland, and the *Graptolites*, have been supposed to belong to the *Polyzoa;* but the former is very possibly a plant, and the latter should be referred to the *Hydrozoa.* Of undoubted *Polyzoa*, the marine orders of the *Cheilostomata* and *Cyclostomata* are alone known with certainty to be represented. Several Palæozoic genera—such as *Fenestella* (the Lace-coral), *Ptilodictya*, *Ptilopora*, &c.—are exclusively confined to this epoch, and do not extend into the Secondary rocks. Amongst the Mesozoic formations, the Chalk is especially rich in *Polyzoa*, over two hundred species having been already described from this horizon alone. In the Tertiary period, the Coralline Crag (Pliocene) is equally conspicuous for the great number of the members of this class.

CHAPTER XLII.

TUNICATA.

Class II. Tunicata (*Ascidioida*).—The members of this class of the *Molluscoida* are defined as follows: "*Alimentary canal suspended in a double-walled sac, but not capable of protrusion and retraction; mouth opening into the bottom of a respiratory sac, whose walls are more or less completely lined by a network of blood-vessels*" (Allman). *Animal simple or composite. An imperfect heart in the form of a simple tube open at both ends. Sexes mostly united; a metamorphosis in development.*

The Tunicaries are all marine, and are protected by a leathery, elastic integument, which takes the place of a shell. In appearance a solitary Ascidian (fig. 200, C) may be compared to a double-necked jar with two prominent apertures situated close to one another at the free extremity of the animal, one of these being an ingestive and branchial aperture, whilst the other serves as an excretory aperture. The covering of an Ascidian is composed of two layers. Of these the outer is

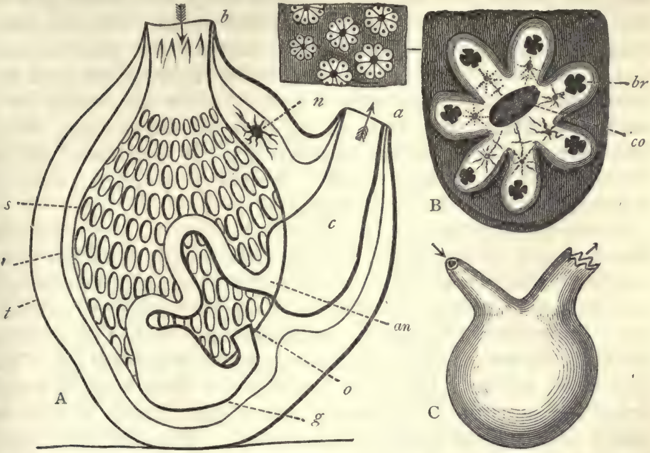

Fig. 200.—Morphology of *Tunicata*. A, Diagram of the structure of a simple Tunicate: *t* Test; *t'* Second muscular tunic; *s* Branchial sac; *b* Branchial aperture; *a* Atrial aperture; *c* Atrium; *o* Opening of the gullet; *g* Stomach, leading into the intestine; *an* Anal aperture; *n* Nerve-ganglion. B, *Botryllus smaragdus*—a small portion of a colony of the natural size, and a single system of the same enlarged; *co* Common atrial aperture; *br* Branchial aperture of one of the zoöids. C, *Molgula Manhattensis*, a simple Ascidian. The arrows in A and C show the direction of the water-currents.

called the "external tunic," or "test," and is distinguished by its generally coriaceous or cartilaginous consistence. It is also remarkable for containing a substance which gives the same chemical reactions as cellulose, and is probably identical with this characteristic vegetable product. Sometimes it contains spicules or plates of calcareous matter. The test is lined by a second coat, which is termed the "second tunic," or "mantle," and which is mainly composed of longitudinal and circular muscular fibres. By means of these the animal is endowed with great contractility, and has the power of ejecting water from its branchial aperture with considerable force. The mantle lines the test, but is only slightly and loosely attached to it, especially near the apertures. The ingestive or branchial aperture (fig. 200, A, *b*) is generally surrounded by a circlet of small, non-ciliated, non-retractile tentacles, and opens into a large chamber (fig. 200, A, *s*), which usually occupies the greater part of the cavity of the mantle, and has its walls perforated by numerous apertures. This is known variously as the "pharynx," the "respiratory sac," or the "branchial sac." The last of these names is the best, as it is not certain that the perforated respiratory sac is really the homologue of the pharynx. If this should be its real nature, then the branchial opening in the test is truly the *mouth;* but good authorities regard the branchial sac as wholly unconnected with the alimentary canal. Inferiorly the respiratory sac leads, by a second aperture (fig. 200, A, *o*), into an œsophagus, which conducts into a capacious stomach (*g*). If the branchial sac be regarded as *not* representing a dilated pharynx, then its lower aperture is the true mouth.

From the stomach an intestine is continued, generally with few flexures, to the anal aperture (*an*), which does not communicate directly with the exterior, but opens into the bottom of a second chamber, which is called the "cloaca," or "atrium" (*c*). Superiorly the cloaca communicates with the external medium, by means of the second aperture in the test (*a*). The first bend of the intestine is such that, if continued, it would bring the anus on the opposite side of the mouth to that on which the nervous ganglion is situated. The intestine, therefore, is said to have a "hæmal flexure;" whereas the flexure in the case of the *Polyzoa* is "neural." The intestine, however, in the *Tunicata* does not preserve this primary hæmal flexure, but is again bent to the neural side of the body, the nervous ganglion coming finally to be situated between the mouth and the rectum. As just stated, the anus is not in direct communication wtth the exterior, but opens into a large cavity, called the "cloaca," or "atrial chamber," which, in turn, opens externally by the second aperture of the animal. This cloaca is a large sac lined by a membrane which "is reflected like a serous sac on the viscera, and constitutes the 'third tunic,' or 'peritoneum.'" From the cloaca "it is reflected over both sides of the pharynx" (respiratory sac), "extending towards its dorsal part very nearly as far as that structure which has been termed the 'endostyle.' It then passes from the sides of the pharynx to the body-walls, on which the right and left lamellæ become continuous, so as to form the lining of the chamber into which the second aperture leads, or the 'atrial chamber.' Posteriorly, or at the opposite end of the atrial chamber to its aperture, its lining membrane (the 'atrial tunic') is reflected to a greater or less extent over the intestine and circulatory organs. . . . Where the 'atrial tunic' is reflected over the sides of the pharynx, the two enter into a more or less complete union, and the surfaces of contact become perforated by larger or smaller, more or less numerous, apertures. Thus the cavity of the pharynx acquires a free communication with that of the atrium; and as the margins of the pharyngo-atrial apertures are fringed with cilia working towards the interior of the body, a current is produced, which sets in at the oral aperture and out by the atrial opening, and may be readily observed in a living Ascidian" (Huxley).

As regards some points in the above description, Professor Allman does not agree with Huxley, but believes, on the other hand, "that the walls of the atrium simply surround the branchial sac, without being reflected on its sides, and that the branchial sac is therefore properly *within* the cavity of the atrium."

In structure, the "branchial" sac is composed of a series of longitudinal and transverse bars, which cross each other at right angles, and thus give rise to a series of quadrangular meshes, the margins of which are fringed with vibratile cilia. These bars are hollow, and are really vessels, which open on each side into two main longitudinal sinuses, the so-called "branchial" or "thoracic" sinuses—one of which is placed along the hæmal side of the sac, whilst the other runs along its neural aspect. The function of the entire perforated sac is clearly respiratory.

The *Tunicata* mostly possess a distinct heart, consisting of a simple muscular tube, which is open at both ends, and is not provided with valves. The circulation is attended with the remarkable peculiarity of being periodically reversed, the blood being propelled in one direction for a certain number of contractions, and being then driven for a like period in an opposite direction; "so that the two ends of the heart are alternately arterial and venous."

The nervous system consists of a single ganglion placed on one side of the oral aperture, between it and the anus, in all known *Tunicata*, except in the aberrant form *Appendicularia*.

The only organs of sense are pigment-spots, or ocelli, usually placed between the oral tentacles, and an auditory capsule, sometimes containing an otolith. These organs, however, are not constantly present.

With the exception of *Doliolum* and *Appendicularia*, all the *Tunicata* are hermaphrodite. Mr Saville Kent, however, is of opinion that *Appendicularia* is the free reproductive zoöid of an Ascidian, bearing to the adult the same relation that the Medusæ do to the Hydroid colony. The reproductive organs are situated in the fold of the intestine, and their efferent duct opens into the atrium. The embryo Tunicate (fig. 201, A and C) is at first generally free, and is mostly shaped like the tadpole of a frog, swimming by means of a long caudal appendage. In one species (*Molgula tubulosa*) the larval form is destitute of a tail, inactive, and amœboid, and it almost immediately attaches itself by means of little outward processes which it develops. Several other species of *Molgula* are also destitute of a tail when in the embryo condition ; but the embryos of those species of the genus which are fixed in the adult state appear to be provided with a caudal appendage. Lastly, the larval caudal appendage has been shown to exhibit a cylindrical rod-like body, which has been paralleled with the *chorda dorsalis* of Vertebrates. The body in question (fig. 200, A) is a kind of cellular rod, which agrees with the notochord of Vertebrates in giving insertion by its sheath to muscles, and which is said to hold an analogous position to the nervous system. In many cases, also, the caudal appendage exhibits in addition diverging rays, which have been compared with the rays of the tails of young fishes.

It is impossible here to enter minutely into the structures which compose the larval Tunicate, the relations of these structures to one another and to the larva as a whole, or their precise homological import. Such important theoretical conclusions have, however, been based upon the interpretation of these structures, that a few words may be directed to this point.

According to the researches of Kowalewsky and Kupffer, the larval Tunicate differs from the *Invertebrata* generally, and agrees with the *Vertebrata* in the fact that the embryo is bicavitary, the nervous system being developed in a dorsal cavity, quite separate from the cavity in which the viscera generally are formed. The axial structures of the tail, as described by the same observers, are stated to commence as a double row of quadrate cells, surrounded by oval muscle-cells, and projecting slightly into the body of the larva, having the visceral canal below, and the neural canal above. When complete, the axis of the tail is said to consist of a cartilaginous elastic axial rod, surrounded by a cellular envelope. According, then, to the views of the observers just mentioned, the axial rod of the tail of the larval Tunicate is the precise equivalent of the "chorda dorsalis" of vertebrate animals, seeing that it is dorsal in position, and that it is intermediate between the neural and visceral cavities. The perforated branchial sac being, further, regarded as a development of the anterior portion of the alimentary canal, is an additional support to this view ; as it can be compared with the dilated and perforated pharynx of the Lancelet (*Amphioxus*) the lowest of the Fishes.

The views sketched out above, though accepted and endorsed by many high authorities, have not been allowed to pass without question. The opinions originally put forward by Kowalewsky as to the essential identity of the developmental processes of the Tunicates and the Vertebrates have been attacked, and many of the most important of his alleged facts have been denied by such well-known authorities as Mecznikow, Dönitz, Giard, Von Baer, and Reichert. Without entering into this controversy further, it will be sufficient to enumerate the more important points which the researches of the observers just mentioned would seem to render more or less probable:—

1. The axial rod of the larval Ascidian is ventral in position, and cannot, therefore, be homologically compared with the "chorda dorsalis" of the Vertebrate embryo. (Von Baer.)

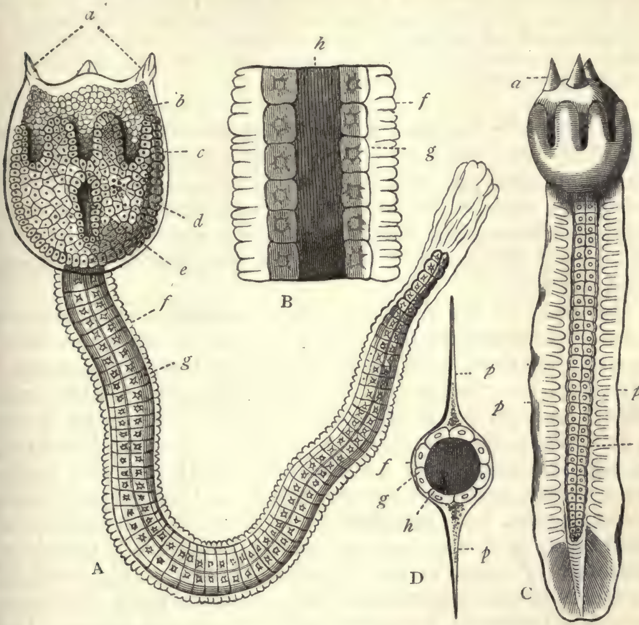

Fig. 201.—Development of *Tunicata*. A, Larva of *Botryllus violaceus*, greatly magnified: *a* Processes for attachment; *b* Mass of primitive cells from which the digestive organs are developed; *c* Circlet of eight cellular outgrowths; *d* Eye-spot; *e* Entrance to the branchial sac; *f* The external structureless "test;" *g* Large nucleated cells forming the sheath of the central axis (eight rows of these cells are present). B, A portion of the tail, highly magnified; *h* Central axis (*f* and *g*, as before). C, Another larva of the same, viewed from the side, and highly magnified, showing the superior and inferior fin-like prolongations (*p p*) of the "test," with ray-like striæ (the other letters as before). D, Diagrammatic cross-section of the tail, showing the position of the fins (*p p*), and the relations to one another of the central axis (*h*), the intermediate cellular sheath (*g*), and the external structureless test (*f*). (After Reichert.)

2. The embryo of the Tunicates is not really bicavitary, and the nervous system is not developed in a chamber separate from and lying above the visceral cavity. (Dönitz, Reichert.)

3. The nerve-ganglion of the Tunicates is placed upon the ventral surface of the larva, and does not, therefore, correspond with the cerebro-spinal nervous system of the Vertebrates. (Von Baer.)

4. The tail of the larval Ascidian is a purely provisional organ.

5. The axial structures of the tail (fig. 201, A, B, and D) consist of a

central homogeneous, structureless, and elastic rod, surrounded by a sheath of large nucleated cells, and the former is not primitively composed of cells. (Reichert.)

6. The perforated branchial sac is not a dilated pharynx, but appears to correspond rather with the branchial chamber of the *Lamellibranchiata.*

From the above, therefore, the general conclusion may safely be drawn, that we are not at present in a position to give a dogmatic account as to even the most important phenomena in the development of the Tunicates. We may further conclude that the view that the development of the Tunicates is fundamentally identical with that of the *Vertebrata* is as yet not to be regarded as scientifically proved.

Amongst the Salpians a species of alternation of generations has been observed. A solitary Salpian produces long chains of embryos, which remain organically connected throughout their entire life. Each individual of these associated specimens produces solitary young, which are often very unlike their parents, and these again give rise to the aggregated forms.*

The *Tunicata* are often spoken of as exhibiting three main types of structure, which give origin to as many sections, known respectively as the *solitary*, the *social*, and the *compound* forms. In the "solitary" Tunicaries (fig. 200, C), the individuals, however produced, remain entirely distinct, or, if not so primitively, they become so. In the "social" Ascidians, the organism consists of a number of zoöids, each like a solitary Ascidian, produced by gemmation and permanently connected together by a vascular canal, or "stolon," composed of a prolongation of the common tunic, through which the blood circulates. Finally, in the "compound" forms (fig. 200, B) the zoöids become aggregated into a common mass, their tests being fused together, but there being no internal union. The Botrylli, which are familiar examples of the compound Tunicates, form semi-transparent masses, often of brilliant colours, attached to various submarine objects, and consisting of numerous zoöids arranged in star-shaped groups. They are almost always "very small, soft, irritable, and contractile, changing their form with the slightest movement" (Stark). The atrial apertures of all the zoöids of each stellate system open into a common central cloaca (fig. 200, B.)

HOMOLOGIES OF THE TUNICATA.—The general resemblance between a solitary Ascidian and a single polypide of a *Polyzoön* is extremely obvious; each consisting of a double-walled sac, containing a freely suspended alimentary canal, with a distinct mouth and anus, and a nervous ganglion placed between the two. The chief feature in the *Tunicata*, as to the exact nature of which there is much difference of opinion, is the branchial or respiratory sac. By Professor Allman this is believed to be truly homologous with the tentacular crown of the *Polyzoa*, and the oral tentacles of the Tunicaries are believed to be something superadded, and not represented at all in the *Polyzoa*. By Professor Huxley, on the other hand, and by many other authorities, the branchial sac is looked upon as an enormously developed pharynx, and the oral tentacles are regarded as a rudimentary representative of the tentacular crown of the *Polyzoa*. Probably the most correct view of the homologies of the *Tunicata* is taken by Rolleston, who regards the "branchial sac" as the homologue of the gills of the ordinary Bivalve Molluscs (*Lamellibranchiata*), whilst the oral and atrial apertures are looked upon as corresponding to the respiratory apertures of these same animals.

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* These cases have been, however, otherwise explained, and asserted to be an abnormal mode of sexual reproduction, the solitary and chained individuals not being the offspring of each other, but being the older and younger progeny of the same parent.

Upon the whole, the systematic position of the *Tunicata* must be looked upon as still unsettled; though they are generally referred either to the *Mollusca* or to the "Worms." A few naturalists regard them either as a special group intermediate between "*Vermes*" and *Vertebrata*, or as actually belonging to the latter sub-kingdom.

DISTRIBUTION OF THE TUNICATA IN SPACE AND TIME.—The Tunicaries are exclusively marine in their distribution, and are principally littoral and shallow-water forms, though some are found at considerable depths, and many are pelagic in habit. The singular *Salpidæ* have the branchial and atrial apertures placed at opposite ends of the body, and are found swimming in the open sea, often in immense shoals. The *Appendicularie*, with their permanent larval tails, are likewise oceanic, as is the cask-shaped *Doliolum*. Lastly, in *Pyrosoma*, we have a singular compound oceanic Tunicate, in which the numerous zoöids form a tubular colony, which is propelled through the water by the united excurrent respiratory jets of its component members. Like the Salpians, it is brilliantly phosphorescent.

On the other hand, the more typical Tunicates are found attached to all kinds of submarine objects, or (as in *Pelonaia*) embedded in mud.

During the "Challenger expedition," some singular deep-sea Tunicates were obtained, and have been since described by Mr Moseley. One of these (*Hypobythius*) was found in the Pacific, at a depth of nearly 3000 fathoms, attached to foreign objects by a peduncle. Its test is hyaline and transparent, and is strengthened by symmetrically disposed cartilaginous plates. *Octacnemus*, dredged at over 1000 fathoms, is also hyaline and transparent, with a short stalk, but it possesses eight long radiating processes, which give it a stellate appearance; and the branchial sac is so flattened as to become nearly horizontal.

No Tunicates are known with certainty to have been preserved in the fossil condition, but the singular Silurian genus *Pasceolus* has been doubtfully referred to this class.

CHAPTER XLIII.

BRACHIOPODA.

Class III. Brachiopoda (*Palliobranchiata*).—The members of this class are defined by the possession of a *body protected by a bivalve shell, which is lined by an expansion of the integument, or "mantle." The mouth is furnished with two long cirriferous arms. The nervous system consists of a single ganglion, placed in the re-entering angle between the gullet and the rectum, so that the intestine has a "neural flexure."*

The *Brachiopoda* are essentially very similar in structure to the *Polyzoa*, from which they are distinguished by the fact that they are never composite, and by the possession of a bivalve, calcareous, or sub-calcareous shell. They are commonly known as "Lamp-shells," and are all inhabitants of the sea. All the living forms, except *Lingula pyramidata*, are fixed to some solid object in their adult condition; but there is good reason to believe that many of the fossil forms were unattached and free in their fully grown condition. From the presence of a bivalve shell, the Brachiopods have often been placed near the true bivalve Mollusca (the *Lamellibranchiata*), but their organisation is very much inferior, and there are also sufficient differences in the shell to justify their separation.

The two valves of the shell of any *Brachiopod* (figs. 202, 204) are articulated together by an apparatus of teeth and sockets, or are kept in apposition by muscular action alone. One of the valves is always slightly, sometimes greatly, larger than the other, so that the shell is said to be "inequivalve." As regards the contained animal, the position of the valves is anterior and posterior, so that they are therefore termed respectively the "ventral" and "dorsal" valves. In the ordinary bivalve *Mollusca* (*Lamellibranchiata*), on the other hand, the two valves of the shell are usually of the same size (equivalve), and they are situated upon the sides of the animal; so that, instead of being dorsal and ventral, they are

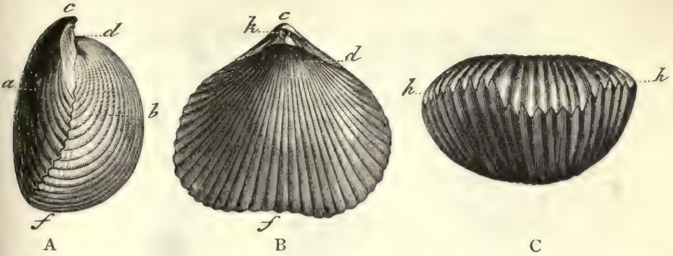

Fig. 202.—*Rhynchonella sulcata*. A, Profile view. B, View of the dorsal surface. C, View of the base. *a* Ventral valve; *b* Dorsal valve; *f* Base; *c* Beak; *h* Foramen. Lower Cretaceous.

now termed "right" and "left" valves. The ventral valve in the shell of the *Brachiopoda* is usually the largest, and usually possesses a prominent curved beak. The beak (figs. 202, 204) is often perforated by a "foramen," or terminal aperture, through which there is transmitted a muscular peduncle, whereby the shell is attached to some foreign object. In some cases, however (as in *Lingula*, fig. 203), the peduncle simply passes between the apices of the valves, and there is no foramen; whilst in others (as in *Crania*, fig. 203, D) the shell is merely attached by the substance of the ventral valve. The dorsal or smaller valve is always free, and is never perforated by a foramen.

In intimate structure, the shell of most of the *Brachiopoda* consists "of flattened prisms, of considerable length, arranged parallel to one another with great regularity, and at a very acute angle—usually only about 10° or 12°—with the surfaces of the shell" (Carpenter). In most cases, also, the shell is perforated by a series of minute canals, which pass from one surface of the shell to the other, in a more or less vertical direction, usually widening as they approach the external surface. These canals give the shells a "punctated" structure, and in the living animal they contain cæcal tubuli, or prolongations, from the mantle, which are considered by Huxley as analogous to the vascular processes by which in many Ascidians the muscular tunic, or "mantle," is attached to the outer tunic, or "test." In some of the *Brachiopoda* (as in the *Rhynchonellidæ*) the shell is "impunctate," or is devoid of this singular canal system.

Though characteristically calcareous, the shell of the *Brachiopoda* may sometimes be largely composed of horny matter (as in *Discina*); or the carbonate of lime in the horny shell may be almost wholly replaced by phosphate (as in *Lingula*).

The inner surface of the valves of the shell is lined by expansions of the integument which secrete the shell, and are called the "lobes" of the "pallium," or "mantle." The digestive organs and muscles occupy a small space near the beak of the shell, which is partitioned off by a membranous septum, which is perforated by the aperture of the mouth. The remainder of the cavity of the shell is almost filled by two long oral processes, which are termed the "arms," and from which the name of the class has been derived (fig. 204, D). These organs are lateral tubular prolongations of the margins of the mouth, usually of great length, closely coiled up, and fringed on one side with ciliated lateral processes, or "cirri." In many Brachiopods the arms are supported upon a more or less complicated internal calcareous framework or skeleton, which is sometimes called the "carriage-spring apparatus," and which in many extinct forms is coiled into a shelly spiral.

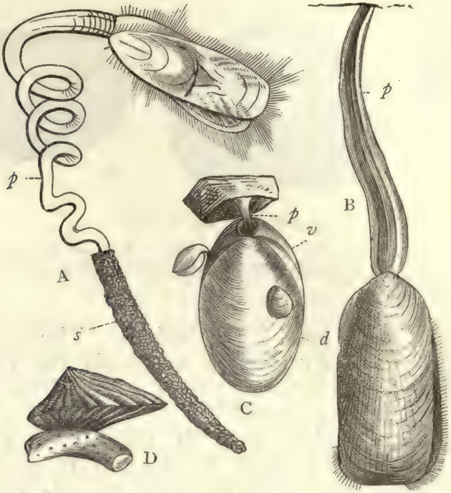

Fig. 203.—Morphology of *Brachiopoda*. A, *Lingula pyramidata* (after Morse): *p* Peduncle; *s* Sand-tube, encasing base of peduncle. B, *Lingula anatina* (after Cuvier); *p* The peduncle. C, *Waldheimia cranium*, with adherent young, attached to a stone (after Davidson): *p* Peduncle; *v* Ventral valve; *d* Dorsal valve. D, *Crania Ignabergensis*, attached by its ventral valve to a piece of coral (Chalk).

The mouth conducts by an œsophagus into a distinct stomach, surrounded by a well-developed granular liver. The intestine has a "neural flexure," and "either ends blindly in the middle line, or else terminates in a distinct anus between the pallial lobes" (Huxley).

Within the pallial lobes there is a remarkable system of more or less branched excretory tubes, anastomosing with one another, and ending in cæcal extremities. This, which has been termed by Huxley the "atrial system," communicates with the perivisceral cavity by means of two or four organs which are called "pseudo-hearts," and which were at one time supposed to be true hearts, but which are now known to be connected with reproduction.

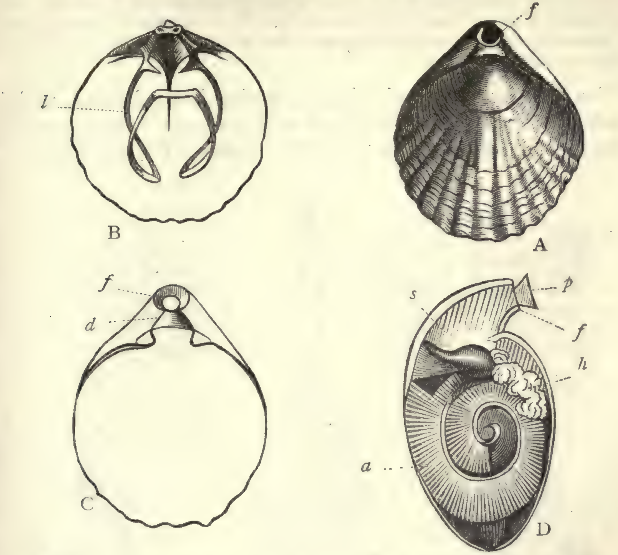

Fig. 204.—*Terebratula* (*Waldheimia*) *flavescens*. A, The shell viewed from behind, showing the dorsal valve, and the perforated summit of the ventral valve above it. B, Inner view of the dorsal valve, showing the shelly loop (*l*) which supports the spiral arms. C, Inner view of the ventral valve, showing the foramen or aperture (*f*) in the beak, through which the muscular stalk of attachment passes. D, Longitudinal and vertical section of the animal, showing the spiral arms (*a*), the stomach (*s*), and the liver (*h*). At *f* is the opening in the beak, with the stalk of attachment (*p*) passing through it. (After Davidson and Owen.) Some details have been omitted in figs. B, C, and D, for the sake of clearness.

"Each pseudo-heart is divided into a narrow, elongated, external portion (the so-called 'ventricle'), which communicates, as Dr Hancock has proved, by a small apical aperture, with the pallial cavity; and a broad, funnel-shaped, inner division (the so-called 'auricle') communicating, on the one hand, by a constricted neck, with the so-called 'ventricle;' and, on the other, by a wide patent mouth, with a chamber which occupies most of the cavity of the body proper, and sends more or less branched diverticula into the pallial lobes" (Huxley). This system of the atrial canals has been looked upon as a rudimentary respiratory apparatus; but its function is more probably to act as an excretory organ, and it certainly serves also to convey away the reproductive elements, the organs for which are developed in various parts of its walls. By Rolleston the pseudo-hearts are looked upon as corresponding with the so-called "organ of Bojanus" of the *Lamellibranchiata.*

The function of respiration is probably performed, mainly, if not entirely, by the cirriferous oral arms, as it appears chiefly to be by the homologous tentacular crown of the *Polyzoa.* A unilocular heart is present in some, but apparently not in all, of the *Brachiopoda;* and the circulation seems to be mainly carried on through the interstices between the tissues.

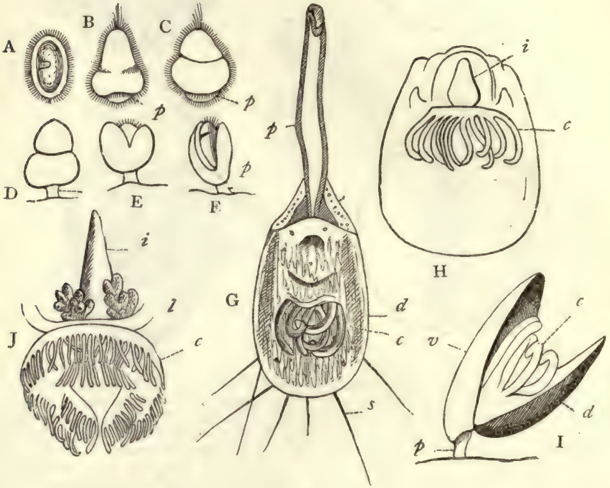

Fig. 205.—Development of *Terebratulina septentrionalis* (after Morse). A, Ciliated embryo. B, More advanced embryo, showing commencing segmentation and a rudimentary peduncle (*p*). C, D, E, F, Further stages of the same embryo. G, Advanced embryo, with a very long peduncle (*p*), and a circular oral crown of cirri (*c*). H, Interior of dorsal valve, showing the circular crown of cirri, and the intestine (*i*). I, Another larva, at the same stage, having the valves opened, and viewed from one side. J, Part of a larva still further advanced, showing the now horse-shoe-shaped crown of cirri; *p* Peduncle; *v* Ventral valve of shell; *d* Dorsal valve; *c* Crown of oral cirri; *i* Intestine; *s* Setæ springing from the edge of the mantle; *l* Loop of dorsal valve. (All the figures are highly magnified.)

The nervous system consists of a principal ganglion of no great size, placed in the re-entering angle between the gullet and the rectum. In those Brachiopods in which the valves of the shell are united by a hinge, the nervous system attains a greater development, and consists of a gangliated œsophageal collar.

The sexes in the *Brachiopoda* appear to be ordinarily distinct, but in some forms they are asserted to be united in the same individual. As regards the process of development in the class, we may take as a type *Terebratulina septentrionalis*, the metamorphoses of which have been most ably worked out by Professor Morse. In this form, the earliest embryo is a ciliated planula (fig. 205, A), which swims about actively, and soon (B) exhibits a division into three regions or segments, which rapidly become more conspicuous (C). Of these segments, the most inferior (*p*) becomes the future peduncle, and serves to attach the embryo to some foreign body (D). The middle segment then enlarges, and partially encloses the anterior segment (E and F), the latter ultimately being withdrawn entirely within the former, which becomes converted into the shell-secreting pallial lobes. Next the arms begin to bud out of the sides of the mouth (G), forming at first a circular crown of cirri (*c*), which forcibly calls to mind the orbicular lophophore of the Gymnolæmatous *Polyzoa.* The peduncle, at first long (as in *Lingula*), becomes rapidly shorter (I), and the oral crown of tentacles becomes distinctly horse-shoe-shaped (J), thus strikingly resembling the similarly-shaped lophophore of the "Hippocrepian" *Polyzoa.* The cirrated "arms" of the adult are finally produced by the growth and development of the free end of the horse-shoe.

Affinities of the Brachiopoda.—Great differences of opinion exist at the present day as to the affinities and precise systematic position of the *Brachiopoda;* but it is impossible to do more here than merely point out these differences. The relationship of the *Brachiopods* to the *Polyzoa* is admitted on all hands to be very close; and we may regard the encrusting members of the latter class as being "communities of Brachiopods, the valves of which are continuous and soldered together, the flat valve forming the united floor, whilst the convex valve does not cover the ventral valve, but leaves an opening more or less ornamented for the extension of the lophophore" (A. Agassiz). Until recently, most naturalists have held that both these groups had strongly-marked relationships with the *Lamellibranchiata*, and many still adhere to this view. On the other hand, the view has been gaining ground, that these groups are to be regarded as comprising modified worms, and they are often placed in the immediate neighbourhood of the *Annelida.* The chief grounds for this view are to be found in the similarity of the development of the Polyzoans and Brachiopods to that of the Annelides, as shewn by the elaborate researches of Morse and Kowalewsky. Apart from embryological likeness, one of the most striking links between the Brachiopods and the Annelides is the aberrant *Lingula pyramidata*—the genus *Lingula* being itself an aberrant type. This curious form (fig. 203, A), as described by Morse, differs from its congeners in not being fixed, but in living free in the sand. Its peduncle is long and wormlike, hollow, and highly contractile, and its lower end is encased in a sand-tube, resembling that of a Tubicolous Annelide. Whilst it must be freely admitted that the affinities between the *Brachiopoda* and the *Annelides* are much closer than any outward resemblance between the two would lead us to expect, a sufficient case for the removal of the former from the *Mollusca* has hardly been made out, except in the view of those who place a supreme value upon embryological characters in classification.

Divisions of the Brachiopoda.—The *Brachiopoda* may be divided into the two orders of the *Inarticulata* (or *Tretenterata*) and the *Articulata* (or *Clistenterata*).

In the first of these orders (*Inarticulata*), the valves of the shell are not united along the hinge-line, the mantle-lobes are completely free, and the intestine terminates in a distinct anus. In this division are included the three families of the *Craniadæ*, *Discinidæ*, and *Lingulidæ*—all very ancient, and all represented at the present day by living forms—together with the Silurian family of the *Trimerellidæ*.

In the second order (*Articulata*), the valves of the shell are united by teeth along the hinge-line, the lobes of the mantle are not completely free, and the intestine ends blindly. In this division are included the living families of the *Terebratulidæ*, *Rhynchonellidæ*, and the *Thecidiidæ*, and the extinct families of the *Spiriferidæ*, *Pentameridæ*, *Strophomenidæ*, and *Productidæ*. In the first two of these families the arms are supported upon a shelly loop, of variable shape and size (fig. 204, B); whilst in some of the extinct *Rhynchonellidæ* and in the *Spiriferidæ*, the arms were supported by large spirally-coiled calcareous lamellæ (fig. 206).

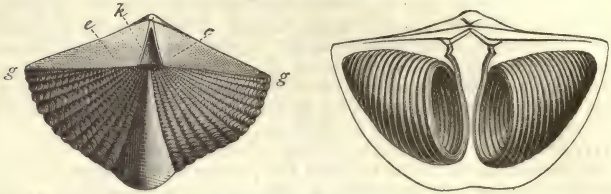

Fig. 206.—*Spirifera hysterica*, from the Carboniferous Limestone. The right-hand figure shows the interior of the dorsal valve, with the calcareous spires for the support of the arms.

DISTRIBUTION OF BRACHIOPODA IN SPACE.—All the known *Brachiopods* live in the sea, and though very local in their distribution, they may be said to have a very wide range. Though sometimes found between tide-marks, and more commonly in comparatively shallow water, they are essentially deep-water forms, living most generally in depths of from 100 to 500 fathoms. A few forms have been found at depths of from 2000 to over 2500 fathoms. About 100 species of living Brachiopods are known.

DISTRIBUTION OF BRACHIOPODA IN TIME.—The *Brachiopoda* are found from the Cambrian Rocks up to the present day, and present us with an example of a group which appears to be slowly dying out. Nearly four thousand extinct species have been described, and the class appears to have attained its maximum in the Silurian epoch, which is, for this reason, sometimes called the "Age of Brachiopods." Numerous genera and species are found also in both the Devonian and Carboniferous formations. In the Secondary Rocks *Brachiopoda* are still abundant, though less so than in the Palæozoic period. In the Tertiary epoch a still further diminution takes place, and at the present day we are not acquainted with more than a hundred living forms. Of the families of *Brachiopoda*, the *Productidæ*, *Strophomenidæ*, and *Spiriferidæ* are the more important extinct types. Of the genera, the most persistent is the genus *Lingula*, which commences in the Cambrian Rocks, and has maintained its place up to the present day, though it appears to be gradually dying out.

According to Woodward:—"The hingeless genera attained their maximum in the Palæozoic age, and only three now survive (*Lingula*, *Discina*, *Crania*)—the representatives of as many distinct families. Of the genera with articulated valves, those provided with spiral arms appeared first, and attained their maximum while the *Terebratulidæ* were still few in number. The subdivision with calcareous spires disappeared with the Liassic period, whereas the genus *Rhynchonella* still exists. Lastly, the typical group, *Terebratulidæ*, attained its maximum in the Chalk period, and is scarcely yet on the decline."

Of the families of the *Brachiopoda*, the *Productidæ* and *Strophomenidæ* are exclusively Palæozoic. The *Spiriferidæ* are mainly Palæozoic, but extend into the Lias, where they finally disappear. The *Lingulidæ* commence in the Cambrian period, and have survived to the present day. The *Rhynchonellidæ*, *Craniadæ*, and *Discinidæ* commence in the Silurian period, and are represented by living forms in existing seas. The *Thecidiidæ* extend from the Trias to the present day; and the *Terebratulidæ* appear to commence in the Upper Silurian, and are well represented by living forms.

MOLLUSCA PROPER.

CHAPTER XLIV.

LAMELLIBRANCHIATA.

Division II. Mollusca Proper.—This division includes those members of the sub-kingdom *Mollusca* in which *the nervous system consists of three principal pairs of ganglia; and there is always a well-developed heart, which is never composed of fewer than two chambers.*

The *Mollusca proper* may be roughly divided into two great sections, respectively termed the *Acephala* and the *Encephala* (or *Cephalophora*), characterised by the absence or presence of a distinctly differentiated head. The headless, or Acephalous, Molluscs correspond to the class *Lamellibranchiata;* also distinguished, at first sight, by the possession of a bivalve shell. The Encephalous Molluscs are more highly organised, and are divided into three classes—viz., the *Gasteropoda*, the *Pteropoda*, and the *Cephalopoda*. The shell in these three classes is of very various nature, but they all possess a singular and complicated series of lingual teeth; hence they are grouped together by Professor Huxley under the name of *Odontophora*.

Class I. Lamellibranchiata, or Conchifera (*Pelecypoda*). —The members of this class are characterised *by the absence of a distinctly differentiated head, and by having the body more or less completely protected in a bivalve shell. There are one or two lamellar gills on each side of the body, the intestine has a neural flexure, and there is no odontophore.*

The *Lamellibranchiata* are commonly known as the "bivalve" shell-fish, such as Mussels, Cockles, Oysters, Scallops, &c., and they are all either marine or inhabitants of fresh water.

Though they agree with the *Brachiopoda* in possessing a shell which is composed of two pieces or valves (small accessory plates are present in *Pholas*, &c.), there are, nevertheless, many points in which the shell of a Lamellibranch is distinguished from that of a Brachiopod, irrespective of the great difference in the structure of the animal in each. The shell in the *Brachiopoda*, as we have seen, is rarely or never quite equivalve, and always has its two sides equally developed (equilateral); whilst the valves are placed antero-posteriorly as regards the animal, one in front and one behind, so that they are "dorsal" and "ventral." In the *Lamellibranchiata*, on the other hand, the two valves are usually of nearly equal size (equivalve), and are more developed on one side than on the other (inequilateral); whilst their position as regards the animal is always *lateral*, so that they are properly termed "right" and "left" valves, instead of "ventral" and "dorsal."

It is to be remembered, however, that many of the Bivalves, such as the Oysters, habitually lie on one side, in which case

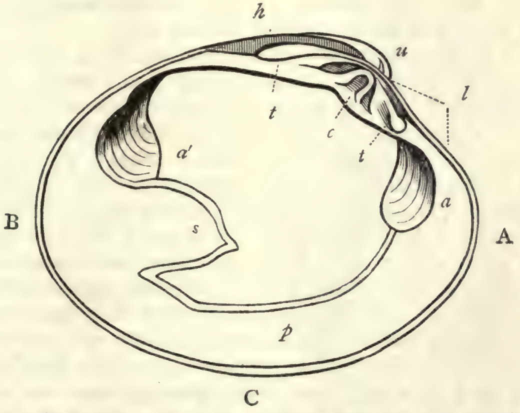

Fig. 207.—Left valve of *Cytherea chione*. (After Woodward.) A, Anterior margin. B, Posterior margin. C, Ventral margin or base; *u* Umbo; *h* Ligament; *l* Lunule; *c* Cardinal tooth; *t t* Lateral teeth; *a* Anterior adductor; *a'* Posterior adductor; *p* Pallial line; *s* Pallial sinus, caused by the retractor muscles of the siphons.

the valves, though really right and left, are called "upper" and "lower." It is to be borne in mind also, that the two valves, especially in the attached Bivalves, may be very unsymmetrical, one valve being much larger or deeper than the other. Lastly, there are some cases (*e.g.*, *Pectunculus*) in which the shell becomes very nearly equilateral, the line drawn from the beaks to the base dividing the shell into two almost equal halves.

The following are the chief points to be noticed in connection with the shell of any Lamellibranch (fig. 207): Each valve of the shell may be regarded as essentially a hollow cone, the apex of which is turned more or less to one side; so that more of the shell is situated on one side of the apex than on the other. The apex of the valve is called the "umbo," or "beak," and is almost always turned towards the mouth of the animal. Consequently, the side of the shell towards which the umbones are turned is the "anterior" side, and it is usually the shortest half of the shell. In some Bivalves, however, the beaks are "reversed," and are turned towards the posterior side of the shell. The longer half of the shell, from which the umbones turn away, is called the "posterior" side, but in some cases this is equal to, or even shorter than, the anterior side. The side of the shell where the beaks are situated, and where the valves are united to one another, is called the "dorsal" side; and the opposite margin, along which the shell opens, is called the "ventral" side, or "base." The *length* of the shell is measured from its anterior to its posterior margin, and its *breadth* from the dorsal margin to the base.

At the dorsal margin the valves are united to one another, for a shorter or longer distance, along a line which is called the "hinge-line." The union is effected in most shells by means of a series of parts which interlock with one another (the "teeth"), but these are sometimes absent, when the shell is said to be "edentulous." Posterior to the umbones, in most Bivalves, is another structure passing between the valves, which is called the "ligament," and which is usually composed of two parts, either distinct or combined with one another. These two parts are known as the "external ligament" (or the ligament proper) and the "cartilage," and they constitute the agency whereby the shell is opened, but one or other of them may be absent. The ligament proper is outside the shell, and consists of a band of horny fibres, passing from one valve to the other just *behind* the beaks, in such a manner that it is put upon the stretch when the shell is closed. The cartilage, or internal ligament, is lodged between the hinge-lines of the two valves, generally in one or more "pits," or in special processes of the shell. It consists of elastic fibres placed perpendicularly between the surfaces by which it is contained, so that they are necessarily shortened and compressed when the valves are shut. To open the shell, therefore, it is simply necessary for the animal to relax the muscles which are provided for the closure of the valves, whereupon the elastic force of the ligament and cartilage is sufficient of itself to open the shell.

Generally the hinge-line is curved, but it is sometimes straight. The beaks are mostly more or less contiguous, but they may be removed from one another to a greater or less distance, and in some anomalous forms they are not near one another at all. In the *Arcadæ* the two beaks are separated from one another by an oval or lozenge-shaped flat space or area. When teeth are present, they differ much in their form and arrangement. In some forms (fig. 207) the teeth are divisible into three sets — one group of one or more teeth, placed immediately beneath the umbo, and known as the "cardinal teeth;" and two groups on either side of the preceding, termed the "lateral teeth." Sometimes there may be lateral teeth only; sometimes the cardinal teeth alone are present; and in some cases (*Arcadæ*) there is a row of similar and equal teeth.

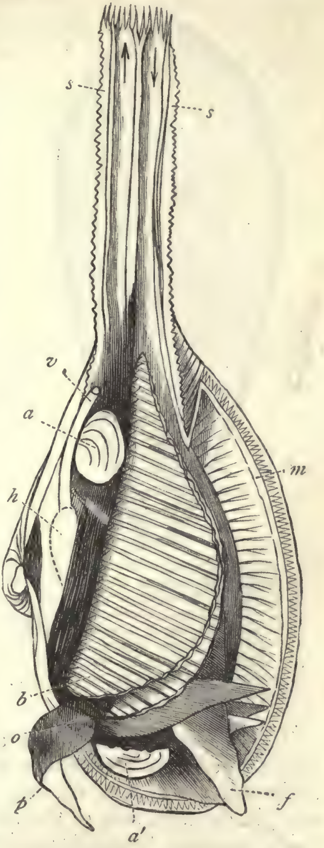

Fig. 208.—Anatomy of a bivalve Mollusc (*Mya arenaria*). The left valve and mantle-lobe and half the siphons are removed. *s s* Respiratory siphons, the arrows indicating the direction of the currents; *a a'* Adductor muscles; *b* Gills; *h* Heart; *o* Mouth, surrounded by (*p*) labial palpi; *f* Foot; *v* Anus; *m* Cut edge of the mantle. (After Woodward.)

The body in the *Lamellibranchiata* is always enclosed in an expansion of the dorsal integument, which constitutes the "mantle," or "pallium," whereby the shell is secreted. The lobes of the mantle are right and left, and not anterior and posterior as are the mantle-lobes of the *Brachiopoda*. Towards its circumference the mantle is more or less completely united to the shell, leaving in its interior, when the soft parts are removed, a more or less distinctly impressed line, which is called the "pallial line," or "impression" (fig. 210).

There is no distinctly differentiated head in any of the *Lamellibranchiata*, and the mouth is simply placed at the anterior extremity of the body. It is furnished with ciliated and tactile membranous processes or "palpi" (usually four in number), but there is no dental apparatus. The mouth opens into a gullet, which conducts to a distinct stomach. On the right side of the stomach, and opening into it, is, in many cases, a blind sac containing a peculiar transparent glassy body, which is known as the "crystalline stylet," but the functions of which are absolutely unknown. The intestine has its first flexure neural, generally perforates the wall of the heart, and terminates posteriorly in a distinct anus, which is always placed near the respiratory aperture. The liver is large and well developed, but there are no salivary glands.

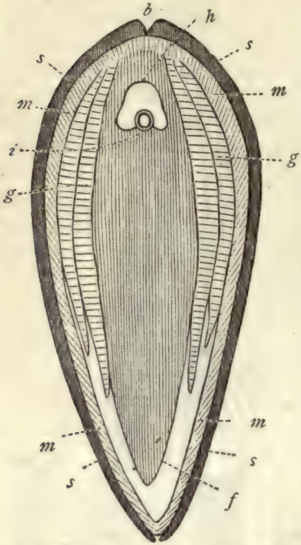

Fig. 209.—Diagrammatic vertical and transverse section of *Mya arenaria.* *b* Back, or "dorsal margin" of the shell; *s s* The two valves of the shell, right and left; *m m* The two halves, or "lobes," of the mantle, producing the shell; *g g* The gills, two pairs on each side; *h* The heart; *i* Intestine; *f* The foot.

There is always a distinct heart, composed either of an auricle and ventricle, or of two auricles and a ventricle. The ventricle propels the blood into the arteries, by which it is distributed through the body. From the arteries it passes into the veins, and is conducted to the gills, where it is aerated, and is finally returned to the auricles.

The respiratory organs in all the *Lamellibranchiata* consist typically of two lamelliform gills, placed on each side of the body (fig. 208, *b* and fig. 209, *g*). In some cases there is only one gill on each side of the body, the external pair of branchiæ being absent. The gills are in the form of membranous plates, composed usually of tubular rods, which support a network of capillary vessels, and are covered with vibrating cilia, whereby a circulation of the water is maintained over their surfaces. In some bivalves the margins of the mantle are united to one another, so that a closed branchial chamber is produced; and in the others the arrangements for the admission of fresh and the expulsion of effete water are equally perfect, though there is no such chamber. In those in which the mantle-lobes are united at their margins, there are two orifices, one of which serves to admit fresh water, whilst the effete water is expelled by the other. The margins of these "inhalant" and "exhalant" apertures are often drawn out and extended into long muscular tubes or "siphons," which may be either free, or may be united to one another along one side (fig. 208, *s s*), and which can usually be partially or entirely retracted within the shell by means of special muscles, called the "retractor muscles of the siphons." These siphons are more especially characteristic of those Lamellibranchs which spend their existence buried in the sand, protruding their respiratory tubes in order to obtain water, and with it such nutrient particles as the water may contain. The presence or absence of retractile siphons can be readily determined merely by inspection of the dead shell. In those bivalves in which siphons are not present, or if present are not retractile, the "pallial line" in the interior of the shell is unbroken in its curvature, and presents no indentation (*Integropallialia*). In those, on the other hand, in which retractile siphons exist, the pallial line does not run in an unbroken curve, but is deflected inwards posteriorly, so as to form an indentation or bay, which is termed the "pallial sinus," or "siphonal impression," and is caused by the insertion of the retractor muscle of the siphon. Those bivalves in which this sinus exists form the section *Sinupallialia* (fig. 210, 2).

The nervous system of the *Lamellibranchiata* is composed of the three normal ganglia—the cephalic, the pedal, and the parieto-splanchnic or branchial. The principal organs of sense are the tactile labial palpi, otocysts, and eye-spots. The otocysts are not always present, and the ocelli, when present, are almost always placed round the edge of the mantle.

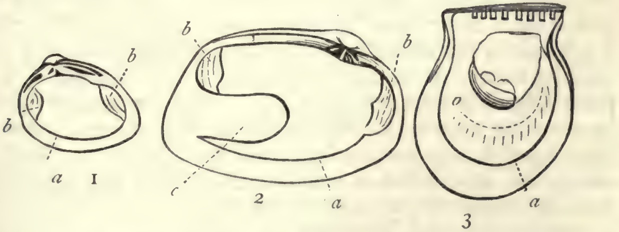

Fig. 210.—Shells of Lamellibranchiata. 1. *Cyclas amnica*, a dimyary shell with an entire pallial line. 2. *Tapes pullastra*, a dimyary shell with an indented pallial line. 3. *Perna ephippium*, a monomyary shell (after Woodward). *a* Pallial line; *b* Muscular impressions left by the adductors; *c* Siphonal impression.

The so-called "organ of Bojanus" of the bivalves is doubtless mainly concerned in excretion, and in all probability represents the kidney. There is one of these organs on each side of the body, each composed of two sacs separated from those of the opposite side by a venous sinus. Or it may be looked upon as a double organ composed of two bilaterally symmetrical halves. It is situated just below the "pericardium" and communicates with it, and also with the mantle-cavity. Though undoubtedly performing the functions of a kidney, the organ of Bojanus is also connected in some cases with reproduction, and it appears to correspond to the "pseudo-hearts" of the *Brachiopoda.*

The majority of the bivalves are diœcious, but in some the sexes are united in the same individual. The young are hatched before they leave the parent, and are, when first liberated, free-swimming, and furnished with a single or double ciliated lobe, constituting what is called the "velum." A long lash-like filament or flagellum is also often present. The velum is wanting in some forms.

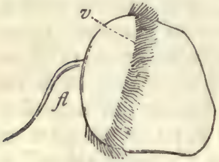

Fig. 211.—Embryo of Cockle (*Cardium*), after Lovén. *v* Ciliated velum; *fl* Flagellum.

The muscular system of the Lamellibranchs is well developed. Besides the muscular margin of the mantle, and the muscles of the siphons (when these exist), there are also present other muscles, of which the most important are the muscles which close the shell and those which form the "foot" (figs. 208 and 209, *f*). The "foot" is present in the majority of bivalves, though it is not such a striking feature as in the *Gasteropoda.* It is essentially a muscular organ, developed upon the ventral surface of the body, its retractor muscles usually leaving distinct impressions or scars (the "pedal impressions") in the interior of the shell. In many, the foot, which is usually compressed, and often sickle-shaped, subserves locomotion, but in the attached bivalves it is rudimentary, and in others (as in the Scallops) locomotion is effected by the alternate opening and closure of the valves. In some—such as the ordinary Mussel—the foot is subsidiary to a special gland, which secretes the tuft of silky threads ("byssus") whereby the shell is attached to foreign objects. This gland secretes a viscous material, which is moulded into threads by grooves on its external surface.

The valves of the shell are brought together by one or two muscles, which are called the "adductor muscles"—those bivalves with only one being called *Monomyaria*, whilst those which possess two are termed *Dimyaria.* In most there are two adductor muscles (fig. 208, *a a'*) passing between the inner surfaces of the valves, one being placed anteriorly in front of the mouth, the other posteriorly on the neural side of the intestine. In the monomyary bivalves the posterior adductor is the one which remains, and the anterior adductor is absent. The adductors leave distinct "muscular impressions" in the interior of the shell, so that it is easy to determine whether there has been one only in any given specimen, or whether two were present.

The habits of the *Lamellibranchiata* are very various. Some, such as the Oyster (*Ostrea*), and the Scallop (*Pecten*), habitually lie on one side, the lower valve being the deepest, and the foot being wanting, or rudimentary. The former is fixed by the substance of the valve, but the latter swims by rapidly opening and closing the shell. Others, such as the Mussel (*Mytilus*) and the *Pinna*, are attached to some foreign object by an apparatus of threads, which is called the "byssus," and is secreted by a special gland. Others are fixed to some solid body by the substance of one of the valves. Many, such as the *Myas*, spend their existence sunk in the sand of the seashore or in the mud of estuaries. Others, as the *Pholades* and *Lithodomi*, bore holes in rock or wood, in which they live. Finally, many are permanently free and locomotive.

The *Lamellibranchiata* may be divided into two sections, according as respiratory siphons are absent or present, as follows:—

SECTION A. ASIPHONIDA.—Animal without respiratory siphons; mantle-lobes free; the pallial line simple and not indented (*Integropallialia*).

This section comprises the families *Ostreidæ*, *Aviculidæ*, *Mytilidæ*, *Arcadæ*, *Trigoniadæ*, and *Unionidæ*.

The *Ostreidæ* (including the Oysters, Scallops, *Anomiæ*, Thorny Oysters, &c.) are all marine, and are monomyary. The *Aviculidæ*, or Pearl-oysters, are likewise marine, but are dimyary. The *Mytilidæ* (Mussels, Horse-mussels, &c.) are partially marine and partially fresh-water forms, and have a very small anterior adductor. The *Arcadæ* (Ark-shells, &c.) are exclusively marine, as are the nearly allied *Trigoniadæ*. Lastly, the *Unionidæ* (Fresh-water Mussels) are exclusively confined to rivers and lakes.

SECTION B. SIPHONIDA.—Animal with respiratory siphons; mantle-lobes more or less united.

Two subdivisions, of little classificatory or anatomical value, are comprised in this section. In the first *the siphons are short, and the pallial line is simple* (*Integropallialia*); as is seen in the families *Chamidæ*, *Hippuritidæ*, *Tridacnidæ*, *Cardiadæ*, *Lucinidæ*, *Cycladidæ*, and *Cyprinidæ*.

The second subdivision (*Sinupallialia*) is distinguished by the possession of *long respiratory siphons*, and *a sinuated pallial line*, and it comprises the families *Veneridæ*, *Mactridæ*, *Tellinidæ*, *Solenidæ*, *Myacidæ*, *Anatinidæ*, *Gastrochænidæ*, and *Pholadidæ*.

The *Chamidæ* (Thorny Clams) are fixed to foreign bodies by the substance of either valve indifferently, and are all inhabitants of the sea. The extraordinary extinct group of the *Hippuritidæ*, from the fossils associated with them, are known to have been also marine; and they are often found in great beds like Oysters, attached to one another and to foreign objects by the beak of the right valve. The *Tridacnidæ* (Giant Clams) have a similar habitat, and the shell may attain a weight of five hundred pounds. The *Cardiadæ* (Cockles) and *Lucinidæ* are also marine, as are the *Cyprinidæ;* but the *Cycladidæ* are fresh-water and brackish-water forms. The *Veneridæ* (Clams) are amongst the most beautiful of the Bivalves, and are found in all seas, attaining their maximum in warm regions. The *Mactridæ* (Trough-shells) and *Tellinidæ* are mostly marine, though also found in brackish waters ; and the *Solenidæ* (Razor-shells), *Myacidæ*, and *Anatinidæ* are essentially marine, though some of the *Myacidæ* extend their range for a considerable distance above the mouths of rivers. The *Gastrochænidæ* are all natives of the sea, and have a burrowing habit, boring holes for habitation in rocks, or living in the mud. Lastly, the *Pholadidæ* (Piddocks and Ship-worms) bore holes in stone or wood, in which they live, and are all marine in habit. The Ship-worms (*Teredo*) have long worm-like bodies, and do an immense amount of harm by honeycombing with their burrows the sides of ships, or other wooden structures immersed in the sea.

DISTRIBUTION OF THE LAMELLIBRANCHIATA IN TIME.—The Lamellibranchs are known to have existed in the Upper Cambrian period, and have steadily increased up to the present day, when the class appears to have attained its maximum, both as regards numbers and as regards variety of type. The recent bivalves are also superior in organisation to those which have preceded them. Upon the whole, the Asiphonate bivalves are more characteristically Palæozoic, whilst those in which the mantle-lobes are united and there are respiratory siphons, are chiefly found in the Secondary and Tertiary epochs. One very singular and aberrant family—viz., the *Hippuritidæ*—is exclusively confined to the Secondary rocks, and is, indeed, not known to occur beyond the limits of the Cretaceous formation. The *Veneridæ*, which are perhaps the most highly organised of the families of the *Lamellibranchiata*, appear for the first time in the Oolitic rocks, and increasing in the Tertiary period, have culminated in the recent period.

CHAPTER XLV.

GASTEROPODA.

Division Encephala, or Cephalophora. — The remaining three classes of the Mollusca proper all possess a distinctly differentiated head, and all are provided with a peculiar masticatory apparatus, which is known as the "odontophore." For the first of these reasons they are often grouped together under the name *Encephala;* and for the second reason they are united by Huxley into a single great division, under the name of *Odontophora.* Whichever name be adopted, the three classes in question (viz., the *Gasteropoda*, *Pteropoda*, and *Cephalopoda*) certainly show many points of affinity, and form a very natural division of the *Mollusca.* The *Pteropoda*, as being the lowest class, should properly be treated of first, but it will conduce to a clearer understanding of their characters if the *Gasteropoda* are considered first.

Class II. Gasteropoda.—The members of this class are *never included in a bivalve shell; locomotion is effected by means of a broad, horizontally flattened, ventral disc—the "foot;" or by a vertically flattened, ventral, fin-like organ. Flexure of intestine hæmal or neural.*

This class includes all those Molluscous animals which have a shell of a single piece, and are commonly known as "univalves," such as the Land-snails, Sea-snails, Whelks, Limpets, &c. The shell, however, is sometimes composed of several pieces (multivalve), and in many there is either no shell at all, or nothing that would be generally recognised as such. In none is there a bivalve shell. The Gasteropods may be regarded as the most typical of the *Mollusca*, though not the most highly organised. All of them have a body composed of three principal portions—a head, foot, and visceral sac—the last of these being enclosed in the integumentary expansion known as the "mantle." In all, except the few sedentary forms, the "foot" is the organ of locomotion.

In most of the *Gasteropoda* the body is unsymmetrical, and is coiled up spirally, "the respiratory organs of the left side being usually atrophied" (Woodward). The body is enclosed in a "mantle," which is not divided into two lobes as in the *Lamellibranchiata*, but is continuous round the body. Locomotion is effected by means of the "foot," which is usually a broad muscular disc, developed upon the ventral surface of the body, and not exhibiting any distinct division into parts. In the *Heteropoda*, however, and in the Wing-shells (*Strombidæ*), the foot exhibits a division into three portions: an anterior, the "propodium;" a middle, the "mesopodium;" and a posterior lobe, or "metapodium." In the *Heteropoda*, the foot is flattened, and forms a ventral fin, by means of which the animal swims, back downwards.

In some, again, the upper and lateral surfaces of the foot are expanded into muscular side-lobes, which are called "epipodia." In many cases the metapodium, or posterior portion of the foot, secretes a calcareous, horny, or fibrous plate, which is called the "operculum" (fig. 215, *o*), and which serves to close the orifice of the shell when the animal is retracted within it.

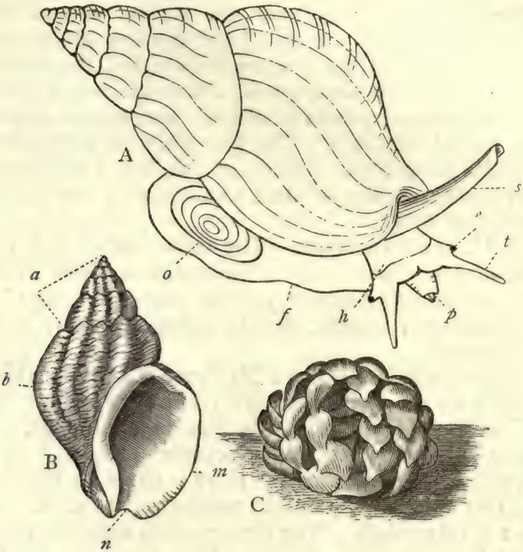

Fig. 212.—A, Sketch of a Whelk (*Buccinum undatum*) in motion: *f* Foot; *h* Head carrying the feelers (*t*) with the eyes (*e*) at their bases; *p* Proboscis; *s* Respiratory siphon, or tube by which water is admitted to the gills; *o* Operculum. B, Shell of the Whelk: *a* Spire; *b* Body-whorl; *n* Notch in the front margin of the mouth of the shell; *m* Outer lip of the mouth of the shell. This figure is half the natural size. C, A small cluster of the egg-capsules of the Whelk. (B and C are after Woodward.)

The head in most of the *Gasteropoda* is very distinctly marked out, and is provided with two tentacles and with two eyes, which are often placed upon long stalks. Very often there is an elongated retractile proboscis, with ear-sacs, containing otoliths, at its base. The mouth is sometimes furnished with horny jaws, and is (with extremely few exceptions) provided with a singular masticatory apparatus, which is variously known as the "lingual ribbon," the "tongue," the "odontophore," or the "radula." This consists of a longer or shorter ribbon-shaped structure, which is attached behind to the bottom of a secreting sac or sheath, situated on the lower wall of the pharynx posteriorly. The lingual ribbon extends forwards along the inferior wall of the pharynx, being supported by a species of cartilaginous cushion, over which it can be made to work backwards and forwards by appropriate muscles. It carries a great number of hook-shaped teeth arranged in transverse rows, there generally being a principal central and two or more lateral rows (fig. 213). These teeth formerly supposed to be siliceous, are now known to be mainly chitinous, and their form and disposition are so various and so constant in different forms, that they afford very valuable help in classification. The mouth leads by a gullet into a distinct stomach, which is sometimes provided with cartilaginous or calcareous plates for the trituration of the food. The intestine is long, and its first flexure is commonly "hæmal," or towards that side of the body on which the heart is situated; though in some the flexure is "neural." Distinct salivary glands are usually present, and the liver is well developed.

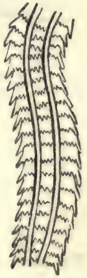
Fig. 213.—Fragment of the lingual ribbon or odontophore of the common Whelk (*Buccinum undatum*), magnified. (After Woodward.)

A distinct heart is almost always present, composed of an auricle and ventricle. In many Gasteropods it has been shown that the blood-vessels form closed tubes, and that the arteries and veins are connected by an intermediate system of capillaries, instead of merely communicating through the interstices and lacunæ between the tissues. It seems also certain that, in general at any rate, there is no direct connection between the blood-vessels and the outer medium, though, in some cases, such a communication seems undoubtedly to exist. Respiration is very variously effected; one great division (*Branchiogasteropoda*) being constructed to breathe air by means of water; whilst in another section (*Pulmogasteropoda*) the respiration is aerial. In the former division respiration may be effected in three ways. Firstly, there may be no specialised respiratory organ, the blood being simply exposed to the water in the thin walls of the mantle-cavity (as in some of the *Heteropoda*). Secondly, the respiratory organs may be in the form of outward processes of the integument, exposed in tufts on the back and sides of the animal (as in the *Nudibranchiata*). Thirdly, the respiratory organs are in the form of pectinated or plume-like branchiæ, contained in a more or less complete branchial chamber formed by an inflection of the mantle. In many members of this last section the water obtains access to the gills by means of a tubular prolongation or folding of the mantle, forming a "siphon" (fig. 214, *s*), the effete water being expelled by another posterior siphon similarly constructed. In the air-breathing Gasteropods, the breathing organ is in the form of a pulmonary chamber, formed by an inflection of the mantle, and having a distinct aperture for the admission of air.

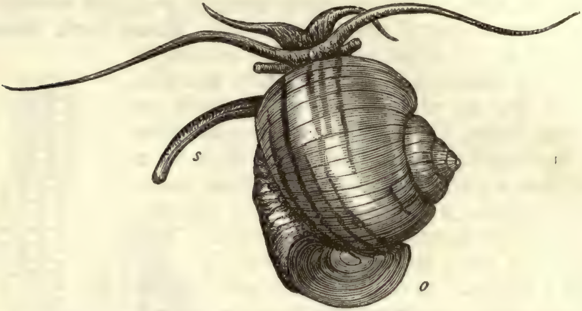

Fig. 214.—*Ampullaria canaliculata*, one of the Apple-shells. *o* Operculum; *s* Respiratory siphon.

The nervous system in the *Gasteropoda* has its normal composition of three principal pairs of ganglia, the supra-œsophageal or cerebral, the infra-œsophageal or pedal, and the parieto-splanchnic; but there is a tendency to the aggregation of these in the neighbourhood of the head. The organs of sense are the two eyes, and auditory capsules placed at the bases of the tentacles, the latter being tactile organs.

The sexes are mostly distinct, but in some they are united in the same individual. The young, when first hatched, are *always* provided with an embryonic shell, which in the adult may become concealed in a fold of the mantle, or may be entirely lost. In the branchiate Gasteropods the embryo (fig. 215, A) is protected by a small nautiloid shell, within which it can entirely retract itself; and it is enabled to swim freely by means of a ciliated, often lobed extension of the cephalic integument, which is termed the "velum," and which is at first merely a circlet of cilia round the head. The velum has often been compared with the wing-like cephalic fins of the *Pteropoda*, with which, however, it is only doubtfully homologous. Amongst the Pulmonate Gasteropods, those which are strictly terrestrial, undergo no metamorphosis, the velum being absent altogether, whereas those that live in fresh water possess structures which correspond with the velum of the Branchiate forms.

Shell of the Gasteropoda.—The shell of the Gasteropods is composed either of a single piece (univalve), or of a number of plates succeeding one another from before backwards (multivalve). The univalve shell is to be regarded as essentially a cone, the apex of which is more or less oblique. In the simplest form of the shell, the conical shape is retained without any alteration, as is seen in the common Limpet (*Patella*). In the great majority of cases, however, the cone is considerably elongated, so as to form a tube, which may retain this shape (as in *Dentalium*), but is usually coiled up into a spiral. The "spiral univalve" (figs. 216, 217) may, in fact, be looked upon as the typical form of the shell in the *Gasteropoda*. In some cases the coils of the shell — termed technically the "whorls"—are hardly in contact with one another (as in *Vermetus*). More commonly the whorls are in contact, and are so amalgamated that the inner side of each convolution is formed by the pre-existing whorl. In some cases the whorls of the shell are coiled round a central axis *in the same plane*, when the shell is said to be "discoidal" (as in the common fresh-water shell *Planorbis*). In most cases, however, the whorls are wound round an axis in an oblique manner, a true spiral being formed, and the shell becoming "turreted," "trochoid," "turbinated," &c. This last form is the one which may be

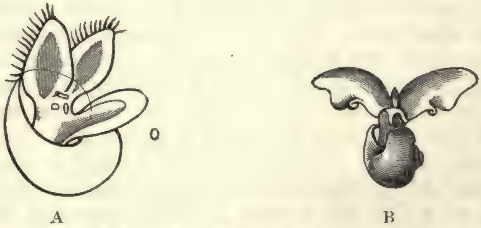

Fig. 215.—A, Young of *Æolis*, a water-breathing Gasteropod, showing the provisional buccal lobes or "velum." B, Adult Pteropod (*Limacina antarctica*). (After Woodward).

looked upon as most characteristic of the Gasteropods, the shell being composed of a number of whorls passing obliquely round a central axis or "columella," having the embryonic shell or "nucleus" at its apex, and having the mouth or "aperture" of the shell placed at the extremity of the last and largest of the whorls, termed the "body-whorl" (fig. 216). The lines or grooves formed by the junction of the whorls are termed the "sutures," and the whorls above the body-whorl constitute the "spire" of the shell. The axis of the shell (columella) round which the whorls are coiled is usually solid, when the shell is said to be "imperforate;" but it is sometimes hollow, when the shell is said to be "perforated," and the aperture of the axis near the mouth of the shell is called the "umbilicus." The margin of the "aperture" of the shell is termed the "peristome," or "peritreme," and is composed of an outer and inner lip, of which the former is often expanded or fringed with spines. When these expansions or fringes are periodically formed, the place of the mouth of the shell at different stages of its growth is marked by ridges or rows of spines, which cross the whorls, and are called "varices." In most of the phytophagous Gasteropods (*Holostomata*) the aperture of the shell (fig. 217) is unbrokenly round or "entire," but in the carnivorous forms (*Siphonostomata*) it is notched, or produced into a canal (fig. 218). Often there are two of these canals, an anterior and a posterior, but they do not necessarily indicate the nature of the food, as their function is to protect the respiratory siphons. The animal withdraws into its shell by a retractor muscle, which passes into the foot, or is attached

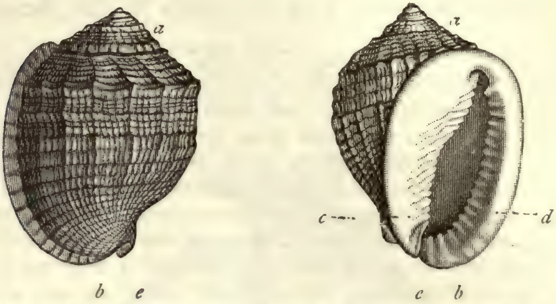

Fig. 216.—Anterior and posterior views of *Cassis cancellata*, a spiral Gasteropod. *a* "Spire," placed at the posterior end of the shell; *b* "Mouth," placed at the anterior end of the shell; *c* Inner or columellar lip; *d* Outer lip; *e* Notch for the passage of a respiratory siphon.

to the operculum; its scar or impression being placed, in the spiral univalves, upon the columella.

In the multivalve Gasteropods, the shell is composed of eight transverse imbricated plates, which succeed one another from before backwards, and are embedded in the leathery or fibrous border of the mantle, which may be plain, or may be beset with bristles, spines or scales.

CHAPTER XLVI.

DIVISIONS OF THE GASTEROPODA.

The *Gasteropoda* are divided into two primary sections or sub-classes, according as the respiratory organs are adapted for breathing air directly or dissolved in water: termed respectively the *Pulmonata*, *Pulmonifera*, or *Pulmogasteropoda*, and the *Branchiata*, *Branchifera*, or *Branchiogasteropoda*.

Sub-class A. Branchifera or Branchiogasteropoda.—In this sub-class *respiration is aquatic*, effected by the thin walls of the mantle-cavity, by external branchial tufts, or by pectinated or plume-like gills, contained in a more or less complete branchial chamber. *Flexure of intestine hæmal.*

This sub-class comprises three orders—viz., the *Prosobranchiata*, the *Opisthobranchiata*, and the *Nucleobranchiata* or *Heteropoda.*

Order I. Prosobranchiata.—The members of this order are defined as follows: "*Abdomen* well developed, and protected by a shell, into which the whole animal can usually retire. *Mantle* forming a vaulted chamber over the back of the head, in which are placed the excretory orifices, and in which the branchiæ are almost always lodged. *Branchiæ* pectinated or plume-like, situated (*proson*) in advance of the heart. *Sexes* distinct" (Milne-Edwards). (See Woodward's 'Manual.')

The order *Prosobranchiata* includes all the most characteristic members of the Branchiate Gasteropods, and is divisible into two sections, termed respectively *Siphonostomata* and *Holostomata*, according as the aperture of the shell is notched or produced into a canal, or is simply rounded and "entire."

The *Siphonostomata*, of which the common Whelk (*Buccinum undatum*, fig. 212) may be taken as an example, are all marine, and are mostly carnivorous in their habits. The following families are comprised in this section: *Strombidæ* (Wing-shells), *Muricidæ*, *Buccinidæ* (Whelks), *Conidæ* (Cones), *Volutidæ*, and *Cypræidæ* (Cowries).

The *Holostomata*, of which the common Periwinkle (*Littorina littorea*) is a good example, are either spiral or limpet-shaped, in some few instances tubular, or multivalve; the aperture of the shell being in most cases entire (fig. 200). They are mostly plant-eaters, and they may be either marine or inhabitants of fresh water. The following families are included in this section: *Naticidæ*, *Pyramidellidæ*, *Cerithiadæ*, *Melaniadæ*, *Turritellidæ*, *Littorinidæ* (Periwinkles), *Paludinidæ* (River-snails), *Neritidæ*, *Turbinidæ* (Top-shells), *Haliotidæ* (Ear-shells), *Fissurellidæ* (Key-hole Limpets), *Calyptræidæ* (Bonnet Limpets), *Patellidæ* (Limpets), *Dentalidæ* (Tooth-shells), and *Chitonidæ*.

The *Dentalidæ* are often regarded as a separate order of the Gasteropods (viz., *Scaphopoda*), or, by Huxley, as referable to the *Pteropoda*. They constitute a lowly-organised group, distinguished by the absence of distinct gills or heart, the imperfect development of the head, and the slender tubular shell, with an aperture at each end.

The *Chitonidæ* and *Patellidæ* are often united into a separate order (*Cyclobranchiata*), characterised by the generally circular disposition of the branchiæ. The former have a multivalve shell, and are stated to have the sexes united.

By many naturalists, the Prosobranchiate order is divided into sub-orders, in accordance with the structure and form of the "odontophore" or "radula."

ORDER II. OPISTHOBRANCHIATA.—This order is defined as follows: "*Shell* rudimentary, or wanting. *Branchiæ* arborescent or fasiculated, not contained in a special cavity, but more or less completely exposed on the back and sides, towards the rear (*opisthen*) of the body. Sexes united" (Milne-Edwards). (See Woodward's 'Manual.')

The *Opisthobranchiata*, or "Sea-slugs," may be divided into two sections, the *Tectibranchiata* and *Nudibranchiata*, according as the branchiæ are protected or are uncovered.

The first section, that of the *Tectibranchiata*, is distinguished by the fact that the animal is usually provided with a shell, both in the larval and adult state, and that the branchiæ are protected by the shell or by the mantle. Under this section are included the families of the *Tornatellidæ*, *Bullidæ* (Bubble-shells), *Aplysiadæ* (Sea-hares), *Pleurobranchidæ*, and *Phyllidiadæ*.

In the second section, that of the *Nudibranchiata* (fig. 219), the animal is destitute of a shell, except in the embryo condition, and the branchiæ (rarely absent, as in *Limapontia* and *Rhodope*) are always placed externally on the back or sides of the body. This section comprises the families *Doridæ* (Sea-lemons), *Tritoniadæ*, *Æolidæ*, *Phyllirhoidæ*, and *Elysiadæ*.

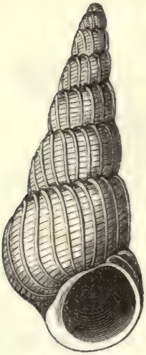

Fig. 217.—*Scalaria Grœnlandica*, a Holostomatous Univalve.

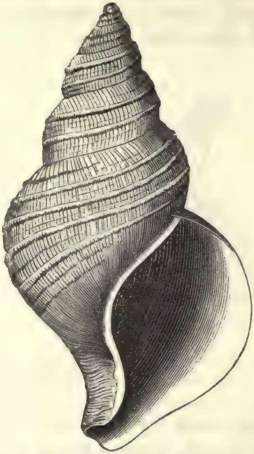

Fig. 218.—*Fusus tornatus*, a Siphonostomatous shell. Post-Pliocene.

Specimens of the Sea-slugs and Sea-lemons may at any time be found creeping about on sea-weeds, or attached to the under surface of stones at low water. The head is furnished with tentacles, which appear to be rather connected with the sense of smell than to be used as tactile organs; and behind the tentacles are generally two eyes. The nervous system is extremely well developed, and would lead to the belief that the *Nudibranchs* are amongst the highest of the *Gasteropoda*. Locomotion is effected, as in the true Slugs, by creeping about on the flattened foot.

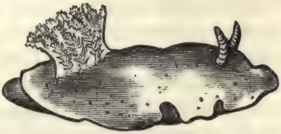

Fig. 219. — Nudibranchiata. *Doris Johnstoni*, one of the Sea-lemons.

ORDER III. NUCLEOBRANCHIATA OR HETEROPODA. — This order is defined by the following characteristics: *Animal provided with a shell, or not, free-swimming and pelagic; locomotion effected by a fin-like tail or by a fan-shaped, vertically-flattened, ventral fin.*

The *Heteropoda* are pelagic in their habits, and are found swimming at the surface of the sea. They are to be regarded as the most highly organised of all the *Gasteropoda*, at the same time that they are not the most typical members of the class. Some of them can retire completely within their shells, closing them with an operculum; but most have large bodies, and the shell is either small (fig. 220) or entirely wanting.

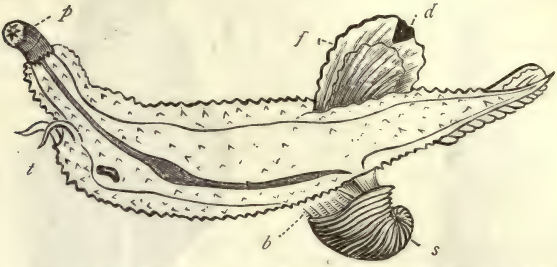

Fig. 220.—Heteropoda. *Carinaria cymbium.* *p* Proboscis; *t* Tentacles; *b* Branchiæ; *s* Shell; *f* Foot; *d* Disc. (After Woodward.)

They swim by means of a flattened ventral fin, or by an elongated tail, and adhere at pleasure to sea-weed by a small sucker situated on the side of the fin. These organs are merely modifications of the foot of the ordinary Gasteropods; the fin-like tail being the "metapodium" (as shown by its occasionally carrying an operculum), the sucker being the "mesopodium," and the ventral fin being a modified "propodium." The "epipodia" are apparently altogether wanting. Respiration is sometimes carried on by distinct branchiæ, but in many cases these are wanting, and the function is performed simply by the walls of the pallial chamber.

The *Heteropoda* are divided into the two families *Firolidæ* and *Atlantidæ*, the former characterised by having a small shell covering the circulatory and respiratory organs, or by having no shell at all; whilst in the latter there is a well-developed shell, into which the animal can retire, and an operculum is often present.

SUB-CLASS B. PULMONIFERA OR PULMOGASTEROPODA.—In this sub-class of the *Gasteropoda respiration is aerial*, and is carried on by an inflection of the mantle, forming a pulmonary chamber into which air is admitted by an external aperture. The *flexure of the intestine is neural*, and the sexes are united in the same individual.

The *Pulmonifera* include the ordinary Land-snails, Slugs, Pond-snails, &c., and are usually provided with a well-developed shell, though this may be rudimentary (as in the Slugs), or even wanting. Though formed to breathe air directly, many of the members of this sub-class are capable of inhabiting fresh water. The common Pond-snails are good examples of these last. The condition of the shell varies greatly. Some, such as the common Land-snails, have a well-developed shell, within which the animal can withdraw itself completely. Others, such as the common Slugs (fig. 221) have a rudimentary shell, which is completely concealed within the mantle. Others are entirely destitute of a shell. They are divided into two sections as follows :—

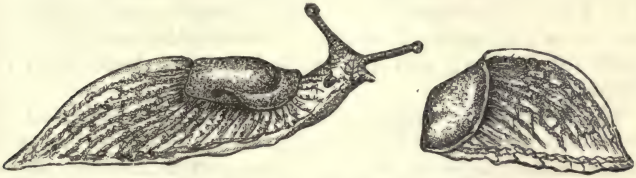

Fig. 221.—*Limax Sowerbyi*, one of the Slugs. (After Woodward.)

Section I. *Inoperculata.—Animal not provided with an operculum to close the shell.* In this section are included the families *Helicidæ* (Land-snails), *Limacidæ* (Slugs), *Oncidiadæ*, *Limnæidæ* (Pond-snails), and *Auriculidæ*.

Section II. *Operculata.—Shell closed by an operculum.* In this section are included the families *Cyclostomidæ* and *Aciculidæ*.

DISTRIBUTION OF THE GASTEROPODA IN SPACE.—As a class the *Gasteropoda* have a world-wide range, some forms being exclusively marine, others inhabiting fresh waters, while others, again, live upon the land. Amongst the *Prosobranchiates*, the entire order of the *Siphonostomata*, and the majority of the *Holostomata*, are marine; but, amongst the latter, the *Melaniadæ* and *Paludinidæ* are confined to fresh waters, and the *Cerithiadæ* and *Neritidæ* include a number of fresh or brackish water forms. The *Opisthobranchiates* are exclusively marine, mostly littoral in their habits, but occasionally oceanic. The *Heteropoda* are exclusively marine and pelagic. Lastly, amongst the *Pulmonates* many forms (such as the Snails and Slugs) are strictly terrestrial, whilst others (*Limnæa*, *Planorbis*, *Ancylus*, &c.) are found in fresh or brackish waters.

DISTRIBUTION OF THE GASTEROPODA IN TIME. — The *Gasteropoda* are represented in past time from the Lower Silurian rocks up to the present day. Of the *Branchifera* the *Holostomata* are more abundant in the Palæozoic period, the *Siphonostomata* abounding more in the Secondary and Tertiary rocks, but not attaining their maximum till the present day. The place of the carnivorous *Siphonostomata* in the Palæozoic seas appears to have been filled by the Tetrabranchiate Cephalopods. The Branchiate Gasteropods of fresh water are chiefly represented as fossils by the genera *Melania*, *Paludina*, *Valvata*, and *Ampullaria*.

The *Heteropoda* are likewise of very ancient origin, having commenced their existence in the lowest Silurian deposits. The genera *Bellerophon*, *Porcellia*, *Cyrtolites*, and *Maclurea*, are almost exclusively Palæozoic; *Bellerophina* is found in the Gault (Secondary), and *Carinaria* has been detected in the Tertiaries.

The Pulmonate *Gasteropoda*, as was to be anticipated, are not found abundantly as fossils, occurring chiefly in lacustrine and estuarine deposits, in which the genera *Limnæa*, *Physa*, *Ancylus*, &c., are amongst those most commonly represented. These, however, are entirely Mesozoic and Kainozoic. In the Palæozoic period the sole known representatives of the *Pulmonifera* are the *Pupa vetusta*, *Pupa vermilionensis*, *Dawsonella Meeki*, and *Zonites priscus* of the Carboniferous rocks.

CHAPTER XLVII.

PTEROPODA.

CLASS III. PTEROPODA.—The *Pteropoda* are defined by being *free and pelagic, swimming by means of two wing-like appendages* (*epipodia*), *developed from each side of the anterior extremity of the body. The flexure of the intestine is neural.*

As to the position of the *Pteropoda* in the Molluscan scale, they must be looked upon as inferior in organisation to any of the *Gasteropoda*, of which class they are often regarded as the lowest division. They permanently represent, from certain aspects, the transient larval stage of the Sea-snails.

The Pteropods are all of small size, and are found swimming at the surface of the open ocean, often in enormous numbers. Locomotion is effected by two wing-like fins, developed from the sides of the head, and composed of the greatly-developed "epipodia." The true "foot" is rudimentary and rarely distinct, but the "metapodium" is sometimes provided with an operculum (*Limacinidæ*). There is usually a symmetrical, glassy, sometimes chitinous, shell (fig. 222), either consisting of a dorsal and ventral plate united, or forming a spiral (fig. 215, B), but in some cases the body is naked, the mantle being absent or rudimentary. The head is rudimentary, and bears the mouth, which is occasionally tentaculate, and which is furnished with an odontophore. There is a muscular stomach and a well-developed liver; and the flexure of the intestine is neural, so that the anus is situated on the lateral or ventral surface of the body.

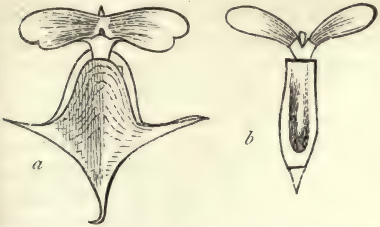

Fig. 222.—Pteropoda. *a Cleodora pyramidata; b Cuvieria columnella.* (After Woodward.)

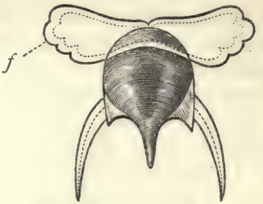

Fig. 223.—*Hyalea tridentata,* showing the shell and the lateral fins attached to the sides of the head (*ff*).

The heart consists of an auricle and ventricle. The respiratory organ is very rudimentary, and consists of a ciliated surface, which is either entirely unprotected, or may be contained in a branchial chamber.

The ganglia of the nervous system "are concentrated into a mass *below* the œsophagus" (Woodward), united by a commissure above the gullet; and the eyes are rudimentary.

The sexes are united in all the Pteropods, and the young pass through a metamorphosis, having at first a bilobed ciliated veil attached to the sides of the head.

The *Pteropoda* are divided into two orders, termed *Thecosomata* and *Gymnosomata;* the former characterised by possessing an external shell and an indistinct head; the latter by being devoid of a shell, and by having a distinct head, with fins attached to the neck.

The *Pteropoda*, as already said, are found swimming near the surface in the open ocean, and they are found in all seas from the tropics to within the arctic circle, sometimes in such numbers as to discolour the water for many miles. They are nocturnal in their habits, and, minute as they are, they constitute in high latitudes one of the staple articles of diet of the whale. They themselves are, in turn, carnivorous, feeding upon small Crustaceans and other diminutive animals. Though all the living forms are small, geology leads us to believe that there formerly existed comparatively gigantic representatives of this class of the *Mollusca*.

Distribution of Pteropoda in Time.—The Pteropods are not largely represented in fossiliferous deposits, but they have a wide range in time, extending from the Upper Cambrian rocks up to the present day. The *Theca* and *Conularia* of the Palæozoic period, if truly Pteropods, are of comparatively gigantic size. Both commence their existence in the Silurian or Upper Cambrian, and the former is entirely Palæozoic. The genus *Conularia*, however, extends into the Mesozoic period, and is found in the Liassic rocks. The Silurian fossils which form the genus *Tentaculites*, though often referred to the Tubicolar Annelides, appear to belong without doubt to the *Pteropoda*. The recent genera *Hyalea* (fig. 223), *Cleodora*, and *Cuvieria* are represented in the Tertiary period.

CHAPTER XLVIII.

CEPHALOPODA.

Class IV. Cephalopoda.—The members of this class are defined by the possession of *eight or more "arms" placed in a a circle round the mouth; the body is enclosed in a muscular mantle-sac, and there are two or four plume-like gills within the mantle. There is an anterior tubular orifice (the "infundibulum" or "funnel") through which the effete water of respiration is expelled. The flexure of the intestine is neural.*

The *Cephalopoda*, comprising the Cuttle-fishes, Squids, Pearly Nautilus, &c., constitute the most highly organised of the classes of the *Mollusca*. They are all marine and carnivorous, and are possessed of considerable locomotive powers. At the bottom of the sea they can walk about, head downwards, by means of the arms which surround the mouth, and which are usually provided with numerous suckers or "acetabula." They are also enabled to swim, partly by means of lateral expansions of the integument or fins (not always present), and partly by means of the forcible expulsion of water through the tubular "funnel," the reaction of which causes the animal to move in the opposite direction.

The majority of the living Cephalopods are naked, possessing only an internal skeleton, and this often a rudimentary one; but the Argonaut (Paper Nautilus), and the Pearly Nautilus, are protected with an external shell, though the nature of this is extremely different in the two forms.

The integument in the Cuttle-fishes is provided with numerous mobile cells, containing pigment-granules of different colours, and termed "chromatophores." By means of these many species can change their colours rapidly, under irritation or excitement.

The body in the *Cephalopoda* is symmetrical, and is enclosed in an integument which may be regarded as a modification of the mantle of the other *Mollusca*. Ordinarily there is a tolerably distinct separation of the body into an anterior cephalic portion (*prosoma*), and a posterior portion, enveloped in the mantle, and containing the viscera (*metasoma*). The head is very distinct, bearing a pair of large globular eyes, and having the mouth in its centre. The mouth is surrounded by a circle of eight, ten, or more, long muscular processes, or "arms" (fig. 224), which are generally provided with rows of stalked or sessile suckers. Each sucker, or "acetabulum," consists of a cup-shaped cavity, the muscular fibres of which converge to the centre, where there is a little muscular eminence or papilla. When the sucker is applied to any surface, the contraction of the radiating muscular fibres depresses the papilla so as to produce a vacuum below it, and in this way each sucker acts most efficiently as an adhesive organ. In some forms (*Decapoda*) the base of the papilla, or piston, is surrounded by a horny dentated ring, and in some others (as in *Onychoteuthis*) the papillæ are produced into long claws. In the Octopod Cuttle-fishes there are only eight arms, and these are all nearly alike. In the Decapod Cuttle-fishes there are ten arms, but two of these—called "tentacles"—are much longer than the others, and bear suckers only at their extremities, which are enlarged and club-shaped. In the

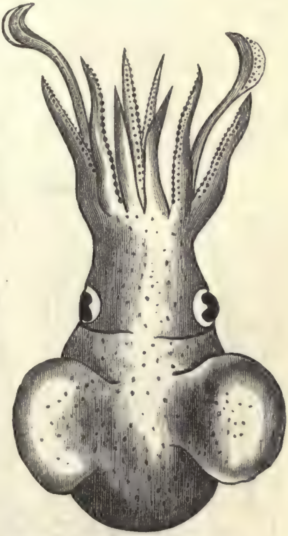

Fig. 224.—Cephalopoda. *Sepiola Atlantica*, one of the Cuttle-fishes. (After Woodward.)

Pearly Nautilus the arms are numerous and are devoid of suckers.

In all the Cuttle-fishes, the mouth is placed in the centre of the "foot," and it is by a splitting up of the margins of the foot into long muscular processes, that the "arms" are produced. The arms are always symmetrically arranged in a dorsal, a ventral, and two lateral pairs; and the "tentacles" (when present) are placed on the ventral surface, between the 3d and 4th pairs of arms. The tentacles may or may not be retractile into pouches placed below the eyes, and their length may be many times greater than that of the body. They are organs of prehension; and the arms are in addition employed by the animal in locomotion, enabling it to creep along the sea-bottom head downward.

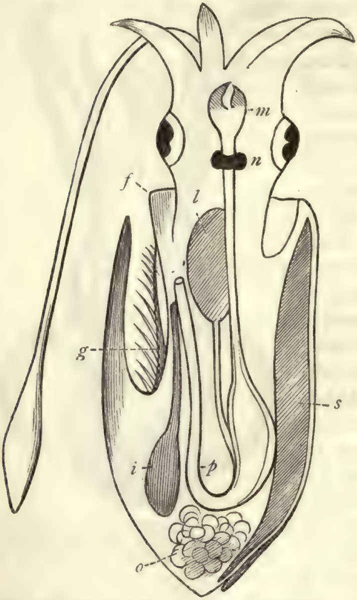

Fig. 225.—Diagram of a Cuttle-fish (altered from Huxley). *m* Mandibles; *n* Cerebral ganglia; *l* Liver; *p* Intestine; *i* Ink-bag; *g* Gill; *f* Funnel; *o* Ovary; *s* Cuttle-bone.

In all the Decapod, and in some of the Octopod forms, the sides of the body are produced into muscular expansions or fins (figs. 224 and 231), with which the animal swims head foremost. In all the Cephalopods, also, the lateral margins of the foot ("epipodia") are either placed in apposition (*Nautilus*) or are actually united (Cuttle-fishes), in such a manner as to form a muscular tube, known as the "funnel." The funnel is placed on the lower surface of the body, with its anterior extremity projecting beyond the mantle, while it opens behind into the pallial chamber. It serves for the elimination of the water which has been used in respiration, and the out-going currents also carry away with them the excretions of the kidneys and of the ink-sac, together with the fæces. By the contractions of the mantle, the water contained in the pallial sac can also be driven through the funnel in a succession of jets, driving the animal backwards through the water.

The mouth leads into a buccal cavity (fig. 225) containing two powerful mandibles, working vertically, resembling the beak of the parrot in shape, and either horny (as in the Cuttle-fishes) or partially calcareous in composition (as in the Nautilus). There is also a muscular tongue which appears to be in part an organ of taste, whilst in part it is developed into a lingual ribbon or "odontophore." The buccal cavity (fig. 225) conducts by an œsophagus—into which salivary glands usually pour their secretion—to a stomach, from which an intestine is continued, with a neural flexure, to open on the ventral surface of the animal at the base of the funnel. A large and well-developed liver is present. In many cases there is also a special gland, called the "ink-bag," for the secretion of an inky fluid, which the animal discharges into the water, so as to enable it to escape when menaced or pursued. The duct of the ink-bag opens at the base of the funnel; but this apparatus is entirely wanting in the Tetrabranchiate Cephalopods, where, in consequence of the presence of an external shell, this means of defence is not needed.

The kidneys (fig. 226, *r r*) are in the form of spongy cellular organs developed upon the two posterior branches of the vena cava. The circulatory organs consist of a systemic central heart (fig. 226, *c*) which drives the aerated blood to all parts of the body. The blood finds its way into the veins mostly through the intervention of a system of capillaries, but also by means of sinuses and lacunæ amongst the tissues. The two great trunks which carry the venous blood to the branchiæ, are further provided, in the Cuttle-fishes, with special contractile dilatations, situated one at the base of each gill, and known as the "branchial hearts" (*e e*).

The respiratory organs are in the form of two (Cuttle-fishes) or four (*Nautilus*) plume-like gills, placed symmetrically on the sides of the body within the pallial sac. The gills (fig. 226, *b b*) consist each of a central stem, bearing finely-divided lateral vascular laminæ; and as they are not ciliated, the necessary respiratory currents are maintained by the alternate contractions and expansions of the muscular walls of the mantle-sac. In each expansion the water finds its way into the pallial chamber by the opening between the rim of the mantle and the neck; and in each contraction it is expelled through the tube of the funnel, which is so constructed as to allow of the egress but to prevent the ingress of the water.

The nervous system consists of the three normal pairs of ganglia—the cerebral, pedal, and parieto-splanchnic—but these are aggregated to form an œsophageal collar (fig. 225, *n*).

The organs of sense are a pair of large and very highly developed eyes, and a pair of auditory sacs. The great œsophageal nerve collar is protected by a cartilaginous plate, which foreshadows the cranium of the *Vertebrata;* this also sends out prolongations which strengthen and defend the eye, and the auditory chambers are excavated in its substance.

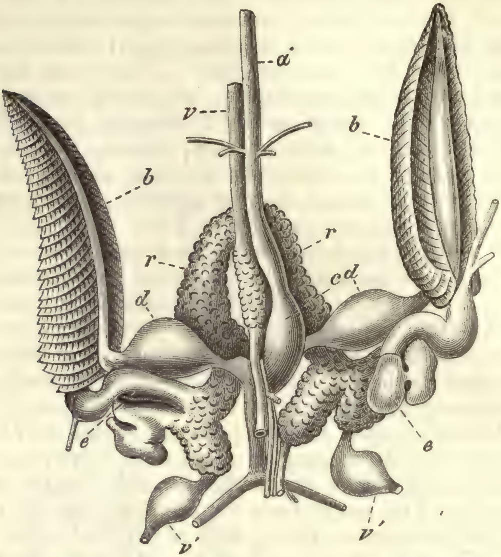

Fig. 226.—Central organs of the circulation, gills, and renal organs of *Sepia officinalis.* (After John Hunter). *a* Aorta; *v* Vena cava; *v' v'* Visceral veins; *c* Systemic heart; *d d* Dilatations of branchial veins on entering the heart; *e e* Branchial hearts; *b b* Branchiæ; *r r* Renal organs.

The sexes in all the *Cephalopoda* are in different individuals, the males and females generally being more or less unlike externally. In this order the ducts of the generative organs open into the pallial chamber, and each individual, besides the essential organs of reproduction (testis or ovary), generally possesses an accessory gland; that of the female secreting a viscid material which unites the eggs together, whilst that of the male coats the spermatozoa, and aggregates them into peculiar worm-like filaments, from six to eight lines in length, termed "spermatophores," or the "moving filaments of Needham." The spermatophore is filled with spermatozoa, and possesses the power of expanding when moistened, rupturing, and expelling the contained spermatozoa with considerable force. During the congress of the sexes the male transfers the spermatophores to the pallial chamber of the female, true intromission not being possible, but the mode in which this transference is effected differs in different cases, and is not universally known.

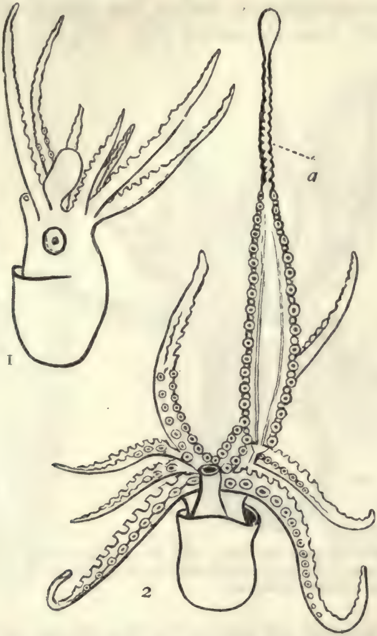

Fig. 227.—1. *Octopus carena* (male), showing cyst in place of the third arm. 2. Ventral side of an individual, more developed, with the hectocotylus (*a*). (After Woodward.)

In the males of many of the Cuttle-fishes, one of the arms is peculiarly modified, and is said to be "hectocotylised," but the extent to which this modification is carried differs in different cases, and it is not always the same arm in different species which is thus affected. In some cases, the "hectocotylised" arm is little altered from its ordinary form, and though the alteration be primarily sexual, the arm is not known to play any part in the reproductive process. In other cases, again, such as *Octopus carena* (fig. 227), *Tremoctopus violaceus* (fig. 228, *b*), and *Argonauta argo* (fig. 228, *a*), the "hectocotylised" arm is the efficient agent in the impregnation of the female.

It is, in these forms, longer and thicker than the other arms, and possesses posteriorly a sac which is filled with spermatophores. During the reproductive act the "hectocotylised" arm is actually detached by the male, and deposited, with its freight of spermatophores, within the pallial chamber of the female. When thus detached (fig. 228, *b*), it is capable of independent movement, and when first found in this free condition within the mantle-cavity of the female Argonaut, it was regarded as a parasitic worm. Cuvier gave the name of "Hectocotylus Octopodis" to it, under this belief as to its nature. Hence the name of "hectocotylus" (in allusion to the suckers which it carries) is still applied to the detached arm; whereas the arm, if not detached, is simply said to be "hectocotylised."

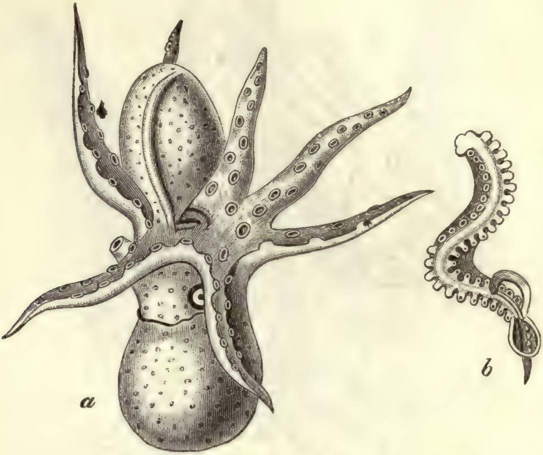

Fig. 228.—*a* Male of *Argonauta argo*, with the hectocotylised arm still contained in its enveloping cyst, four times enlarged (after H. Müller); *b* Hectocotylus of *Tremoctopus violaceus*. (After Kölliker.)

In those cases in which the hectocotylised arm is not detached, it is asserted by Steenstrup that it is employed by the male in the direct transference of the spermatophores to the pallial chamber of the female; though it is still uncertain how the spermatophores find their way from the seminal ducts to the sac in the interior of the arm.

The eggs of the Cuttle-fishes are enclosed, singly or many together, in special capsules, which are generally attached in bunches to some foreign body. The ovum undergoes partial segmentation, as in Birds and Reptiles, and the unsegmented portion of the yolk is gradually absorbed by the growing embryo.

The *shell* of the *Cephalopoda* is sometimes external, sometimes internal. The internal skeleton (fig. 229) is known as the "cuttle-bone," "sepiostaire," or "pen" (*gladius*), and may be either corneous or calcareous. In some cases it is rendered complex by the addition of a chambered portion or "phragmacone," which is to be regarded as a visceral skeleton or "splanchnoskeleton." In *Spirula* (fig. 229, *c*) the phragmacone is the sole internal skeleton, and is coiled into a spiral, the coils of which lie in one plane, and are near one another, but not in contact. It thus resembles the shell of the Pearly Nautilus, but it is *internal*, and differs, therefore, in this respect from the *external* shell of the latter, though resembling it in the fact that the last chamber lodges part of the viscera. The only living Cephalopods which are provided with an external shell are the Paper Nautilus (*Argonauta*), and the Pearly Nautilus (*Nautilus pompilius*); but not only is the structure of the animal different in each of these, but the nature of the

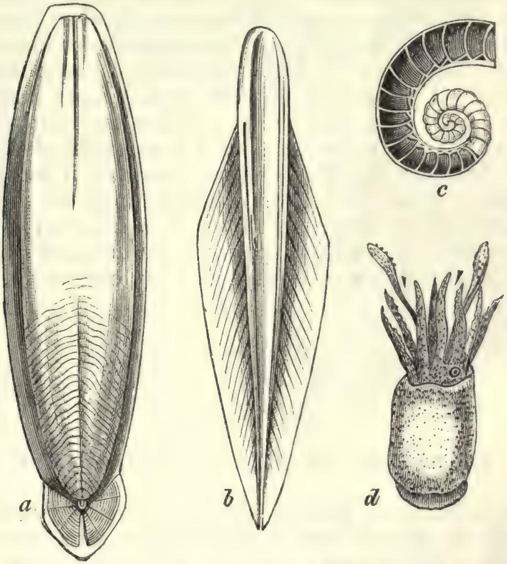

Fig. 229.—*a* Internal Skeleton of *Sepia ornata*; *b* Pen of *Histioteuthis Bonelliana*; *c* Shell ("phragmacone") of *Spirula fragilis*; *d* Animal of *Spirula Peronii*.

shell itself is entirely different. The shell of the Argonaut (fig. 230) is involuted, but is not divided into chambers, and it is secreted by the webbed extremities of two of the dorsal arms of the female. The arms are bent backwards, so as to allow the animal to live in the shell, but there is in reality no organic connection between the shell and the body of the animal. In fact, the shell of the Argonaut, being confined to the female, and serving by its empty apex as a receptacle for the ova, may be looked upon as a "nidamental shell," or, as it is secreted by a modified portion of the foot, it may more properly be regarded as a "pedal shell." The shell of the Pearly Nautilus (fig. 233), on the other hand, is a true pallial shell, and is secreted by the body of the animal, to which it is organically connected. It is involuted, but it differs from the shell of the Argonaut in being divided into a series of chambers by shelly partitions or septa, which are pierced by a tube or "siphuncle," the animal itself living in the last chamber only of the shell.

CHAPTER XLIX.

DIVISIONS OF THE CEPHALOPODA.

THE *Cephalopoda* are divided into two extremely distinct and well marked orders, termed the *Dibranchiata* and *Tetrabranchiata*. The former comprises all the true Cuttle-fishes; whilst the latter, though abundantly represented in past time, has no other living representative than the Pearly Nautilus alone.

ORDER I. DIBRANCHIATA.—The members of this order of the *Cephalopoda* are characterised as being *swimming animals, almost invariably naked, with never more than eight or ten arms, which are always provided with suckers. There are two branchiæ, which are furnished with branchial hearts; an ink-sac is always present; the funnel is a complete tube, and the shell is internal, or, if external, is not chambered.*

The Cuttle-fishes are rapacious and active animals, swimming freely by means of the jet of water expelled from the funnel. The arms constitute powerful offensive weapons, being excessively tenacious in their hold, and being sometimes provided with a sharp claw in the centre of each sucker. They are mostly nocturnal or crepuscular animals, and they sometimes attain to a great size. They may be divided into two sections, *Octopoda* and *Decapoda*, according as they have simply eight arms, or eight arms and two additional "tentacles."

SECTION A. OCTOPODA.—The Cephalopods comprised in this section are distinguished by the possession of not more than eight arms, which are provided with sessile suckers. The shell is internal and rudimentary; in one instance only (the Argonaut) external. The body is short and bursiform, and ordinarily without fins.

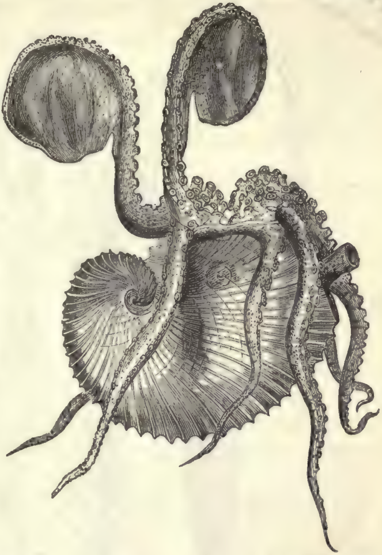

Fig. 230.—*Argonauta argo*, the "Paper Nautilus," female. The animal is represented in its shell, but the webbed dorsal arms are separated from the shell, which they ordinarily embrace.

This section comprises the two families of the *Argonautidæ*, and the *Octopodidæ*. In the former of these there is only the single genus *Argonauta* (the Paper Sailor, or the Paper Nautilus), of which the female and male differ greatly from one another. The female Argonaut (fig. 230) is protected by a thin *single-chambered* shell, in form symmetrical and involuted, which is secreted by the webbed extremities of the dorsal arms, but is not attached in any way to the body of the animal. It sits in its shell with the funnel turned towards the keel, and the webbed arms applied to the shell. The male Argonaut is much smaller than the female (less than an inch in length), and is not protected by any shell. The third left arm of the male (fig. 228) is developed in a cyst, and ultimately becomes a "hectocotylus," and is deposited by the male in the pallial chamber of the female.

In the *Octopodidæ* (or Poulpes) there are eight arms, all similar to one another, and united at the base by a web. There is an internal rudimentary shell, represented by two short styles encysted in the substance of the mantle (Owen). The body is seldom provided with lateral fins. The third right arm of the male is primarily developed in a cyst, and ultimately becomes "hectocotylised."

SECTION B. DECAPODA.—The Cephalopods of this section have eight arms and two additional "tentacles," which are much longer than the true arms, are retractile, and have expanded, club-shaped extremities (fig. 231). The suckers are pedunculated; the body is always provided with lateral fins, and the shell is always internal.

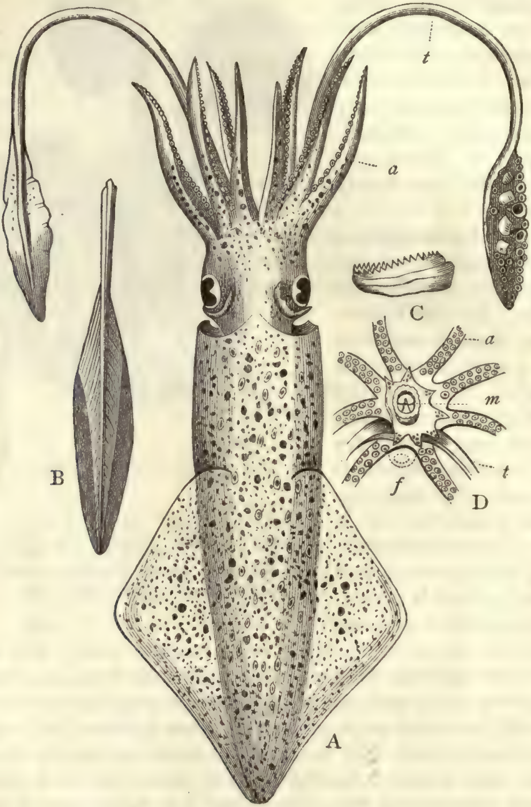

Fig. 231.—A, The common Calamary (*Loligo vulgaris*), reduced in size: *a* One of the ordinary arms; *t* One of the longer arms or "tentacles." B, Skeleton or "pen" of the same, one-fourth natural size (after Woodward). C, Side view of one of the suckers, showing the horny hooks surrounding the margin. D, View of the head from in front, showing the bases of the arms (*a*) and tentacles (*t*), the mouth (*m*), and the funnel (*f*).

This section comprises the three living families of the

Teuthidæ, *Sepiadæ*, and the *Spirulidæ*, and the extinct family of the *Belemnitidæ*.

The family of the *Teuthidæ* comprises the Calamaries or Squids (fig. 231), characterised by the possession of an elongated body with lateral fins. The shell (fig. 229, *b*) is internal and horny, consisting of a median shaft and of two lateral wings; it is termed the "gladius" or "pen," and in old specimens several may be found lodged in the mantle, one behind the other. In the common Calamary (*Loligo*) the fourth left arm of the male is metamorphosed towards its extremity to subserve reproduction.

In the family of the *Sepiadæ* the internal shell (fig. 229, *a*) is calcareous ("cuttle-bone" or "sepiostaire"), and is in the form of a broad plate, having an imperfectly-chambered apex. The broad laminated plate is extremely light and spongy, and the chambered apex is called the "mucro." In the living members of the family the body is provided with long lateral fins, sometimes as long and as wide as the body itself.

In the singular family of the *Spirulidæ* the internal skeleton (fig. 229, *c*) is in the form of a nacreous, discoidal shell, the whorls of which are not in contact with one another, and which is divided into a series of chambers by means of partitions or septa which are pierced by a ventral tube or "siphuncle." The body is provided with minute lateral fins, and the arms have six rows of small suckers. The shell of the *Spirula*—commonly known as the "post-horn"—is similar in structure to the shell of the *Nautilus*, but it is lodged in the posterior part of the body of the animal (fig. 229), and is therefore *internal*, whereas the shell of the latter is *external*. It really corresponds to the "phragmacone" of the Belemnite. Though the shell occurs in enormous numbers in certain localities, a single perfect specimen of the animal is all that has been hitherto obtained. In its internal anatomy, *Spirula* is a true Dibranchiate. It has the peculiar feature that the hinder end of the body forms a kind of suctorial disc, apparently employed to moor the animal to foreign bodies. The beaks are not calcified. The retractor muscles of the funnel spring from the inner surface of the last chamber of the shell (as in *Nautilus*); and this chamber also lodges the hinder termination of the liver (Owen).

In the extinct family of the *Belemnitidæ*, our knowledge is chiefly confined to the hard parts. Certain specimens however, have been discovered, which show that the *Belemnite* had essentially the structure of a Cuttle-fish, such as the recent Calamary. The body was provided with lateral fins; the arms were eight, furnished with horny hooks, with two "tentacles;" and probably the mouth was provided with horny mandibles. An ink-bag was present. The internal skeleton of a *Belemnite* (fig. 232) consists of a chambered cone—the "phragmacone"—the septa of which are pierced with a marginal tube or "siphuncle." In the last chamber of the phragmacone is contained the ink-bag, often in a well-preserved condition. Anteriorly the phragmacone is continued into a horny lamina or "pen" (the "pro-ostracum" of Huxley), and posteriorly it is lodged in a conical sheath or "alveolus," which is excavated in the substance of a nearly cylindrical, fibrous body, the "guard" (fig. 232, *g*) which projects backwards for a longer or shorter distance, and is the part most usually found in a fossil condition.

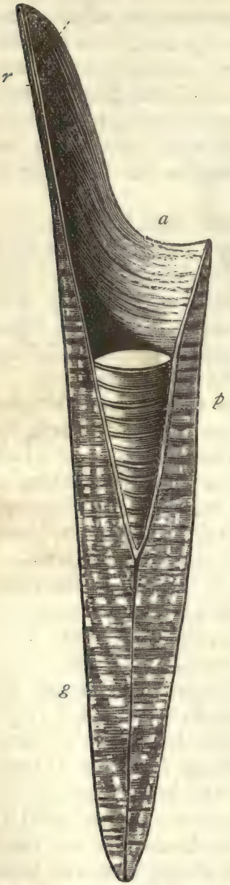

Fig. 232.—Diagram of Belemnite (after Professor Phillips). *r* Horny pen or "pro-ostracum;" *p* Chambered "phragmacone" in its cavity (*a*) or "alveolus;" *g* "Guard."

ORDER II. TETRABRANCHIATA.—The members of this order of the *Cephalopoda* are characterised by being *creeping animals, protected by an external, many-chambered shell, the septa between the chambers of which are perforated by a membranous or calcareous tube termed the "siphuncle." The arms are numerous and are devoid of suckers; the branchiæ are four in number, two on each side of the body; the funnel does not form a complete tube; and there is no ink-bag.*

Though abundantly represented by many and varied extinct forms, the only living member of the *Tetrabranchiata* is the Pearly Nautilus, which has been long known by its beautiful chambered shell, but the soft parts of which were first described from a perfect specimen which was examined by Professor Owen.*

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* The animal of the Pearly Nautilus is still one of the greatest rarities in museums. Its anatomy was originally described from a female specimen

The soft structures in the Pearly Nautilus may be divided into a posterior, soft, membranous mass (*metasoma*), containing the viscera, and an anterior muscular division, comprising the head (*prosoma*); the whole being contained in the capacious outermost chamber (the body-chamber) of the shell, from which the head can be protruded at will. The shell itself (fig. 233) is involuted and many-chambered, the animal being contained successively in each chamber, and retiring from it as its size becomes sufficiently great to necessitate the acquisition of more room. Each chamber, as the animal retires from it, is walled off by a curved, nacreous septum; the communication between the chambers being still kept up by a membranous tube or siphuncle, which opens at one extremity into the pericardium, and is continued through the entire length of the shell. The position of the siphuncle is in the centre of each septum, but the siphuncle simply passes through the chambers, without opening into them.

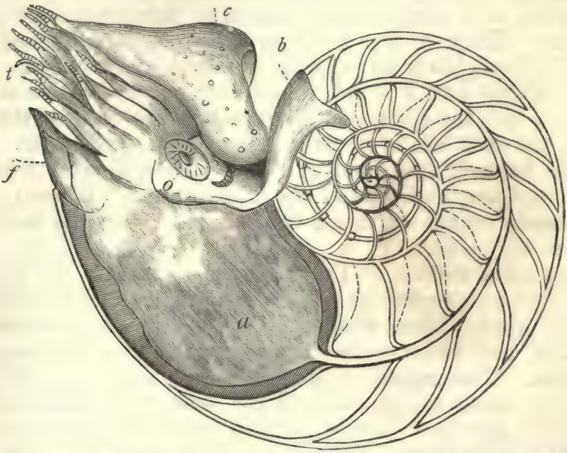

Fig. 233.—Pearly Nautilus (*Nautilius pompilius*). *a* Mantle; *b* Its dorsal fold; *c* Hood; *o* Eye; *t* Tentacles; *f* Funnel.

Posteriorly the mantle of the Nautilus is very thin, but it is much thicker in front, and forms a thick fold or collar surrounding the head and its appendages. From the sides of the head spring a great number of muscular prehensile processes or "arms," which are annulated, but are not provided with

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by Prof. Owen in 1832. Since that time examples have been described by Van der Hoeven, Vrolik, Valenciennes, Macdonald, &c.

cups or suckers. Four of the arms of the male are specially modified to form a peculiar organ termed the "spadix," which is connected with reproduction, and corresponds with the "hectocotylised" arm of the male Cuttle-fishes. In the centre of the head is the mouth, surrounded by a circular fleshy lip, external to which is a series of labial processes. The mouth opens into a buccal cavity, armed with two horny mandibles, partially calcified towards their extremities, and shaped like the beak of a parrot, except that the under mandible is the longest. There is also a "tongue," which is fleshy and sentient in front, but is armed with recurved teeth behind. The gullet opens into a large crop, which in turn conducts to a gizzard, and the intestine terminates at the base of the funnel. On each side of the crop is a well-developed liver.

The heart is contained in a large cavity, divided into several chambers, and termed the "pericardium" (Owen). The respiratory organs are in the form of four pyramidal branchiæ, two on each side.

The chief masses of the nervous system are the cerebral and infra-œsophageal ganglia, which are partially protected by a cartilaginous plate, which is to be regarded as a rudimentary cranium, and which sends out processes for the attachment of muscles. The organs of sense are two large eyes, attached by short stalks to the sides of the head, two spheroidal ear-capsules, and two hollow plicated subocular processes, believed to be possibly olfactory in their function.

The reproductive organs of the female consist of an ovary, oviduct, and accessory nidamental gland.

There is no ink-bag, and the funnel does not form a complete tube, but consists of two muscular lobes, which are simply in apposition. It is the organ by which swimming is effected, the animal being propelled through the water by means of the reaction produced by the successive jets emitted from the funnel. The function of the chambers of the shell appears to be that of reducing the specific gravity of the animal to near that of the surrounding water, since they are most probably filled with some gas secreted by the animal. Good authorities, however, believe that the chambers of the shell are filled with water. The function of the siphuncle is unknown, except in so far as it doubtless serves to maintain the vitality of the shell.

SHELL OF THE TETRABRANCHIATA.—The shells of all the *Tetrabranchiata* agree in the following points:—

1. The shell is external.
2. The shell is divided into a series of chambers by plates

or "septa," the edges of which, where they appear on the surface of the shell, are termed the "sutures."

3. The outermost chamber of the shell is the largest, and is the one inhabited by the animal.

4. The various chambers of the shell are traversed by a tube, termed the "siphuncle."

Agreeing in all these fundamental points of structure, two very distinct types of shell may be distinguished as characteristic of the two families *Nautilidæ* and *Ammonitidæ*, into which the order *Tetrabranchiata* is divided.

In the family *Nautilidæ* (fig. 234, *d* and *e*), the "septa" of the shell are simple, curved, or slightly lobed; the "sutures" are more or less completely plain; and the "siphuncle" is central, sub-central, or internal (*i.e.*, on the *concave* side of the curved shells).

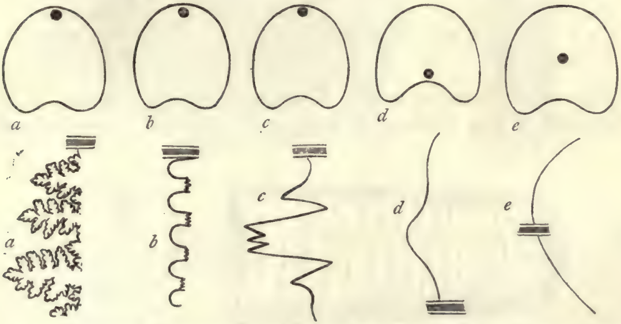

Fig. 234.—Diagram to illustrate the position of the siphuncle and the form of the septa in various Tetrabranchiate Cephalopoda. The upper row of figures represents transverse sections of the shells, the lower row represents the edges of the septa. *a a Ammonite* or *Baculite; b b Ceratite; c c Goniatite; d d Clymenia; e e Nautilus* or *Orthoceras.*

In the family *Ammonitidæ* (fig. 234, *a*, *b*, and *c*), on the other hand, the septa are folded and complex; the sutures are angulated, zigzag, lobed, or foliaceous; and the siphuncle is external (*i.e.*, on the *convex* side of the curved shells).*

In both these great *types* of shell, a series of representative *forms* exists, resembling each other in the manner in which the shell is folded or coiled, but differing in their fundamental structure. All these different forms may be looked upon as produced by the modification of a greatly elongated cone, the structure of which may be in conformity with the type either of the *Nautilidæ* or of the *Ammonitidæ*. The following table (after Woodward) exhibits the representative forms in the two families :—

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* In the *Ammonitidæ*, the initial chamber ("ovisac") of the shell is an egg-shaped chamber isolated from the first air-chamber by a distinct constriction, whereas no such arrangement obtains in the *Nautilidæ*. Such a structure, however, is found in *Spirula*, *Belemnites*, and other allied forms; and it has recently been concluded (Munier-Chalmas) that the *Ammonitidæ* are properly *Dibranchiate*, their shell being an internal skeleton or phragmacone, similar to the shell of the *Spirula*.

	Nautilidæ.	*Ammonitidæ.*
Shell straight, ...	Orthoceras, .	Baculites.
„ bent on itself, . . .	Ascoceras, . .	Ptychoceras.
„ curved, ...	Cyrtoceras, .	Toxoceras.
„ spiral, ...	Trochoceras, .	Turrilites.
„ discoidal, ...	Gyroceras, . .	Crioceras.
„ discoidal and produced,	Lituites, . . .	Ancyloceras.
„ involute, ...	Nautilus, . .	Ammonites.

After the *Nautilus* itself, the most important form of the *Nautilidæ* is the *Orthoceras* (fig. 235). In structure this was doubtless essentially identical with the Nautilus, but the shell, instead of being coiled into a spiral lying in one plane, was extended in a straight, or nearly straight, line. Orthoceratites of more than six feet in length have been discovered, but in all, the body-chamber, in which the animal was lodged, appears to have been comparatively small. The siphuncle is usually very complex in structure, and was calcareous throughout its entire length.

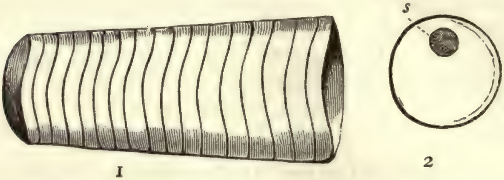

Fig. 235.—*Orthoceras explorator*, Billings. 1. Side view of a fragment, showing the septa. 2. Transverse section of the same, showing (*s*) the siphuncle.

The structure of the shell in the *Ammonitidæ* is exactly that of the Pearly Nautilus, consisting of an outer porcellanous and an inner nacreous layer. The body-chamber was rather elongated than laterally expanded or dilated. The simplest form of the *Ammonitidæ* is the *Baculite*, in which the shell is straight, like that of an *Orthoceras*, while the septa have the characters of those of an *Ammonite*, and the siphuncle is external. In the *Turrilite* (fig. 237) the structure of the shell is the same, but it is coiled into a turreted spiral. In the *Am-*

monite itself (fig. 236), the shell is discoidal and involuted, corresponding (in *form*) to the shell of the *Nautilus*; the body-chamber was of comparatively large size, and had its aperture closed, in some species at any rate, by an operculum. The shell sometimes attained a gigantic size, and several hundred species of the genus have been described. In *Crioceras* (fig. 237) the shell was a flat spiral, like that of the Ammonites, but the whorls are not in contact. In *Toxoceras* the shell is shaped like a bow. In *Ancyloceras* (fig. 237) the shell is at first discoidal, with separate whorls, then produced into a straight line, and finally bent forwards into a hook.

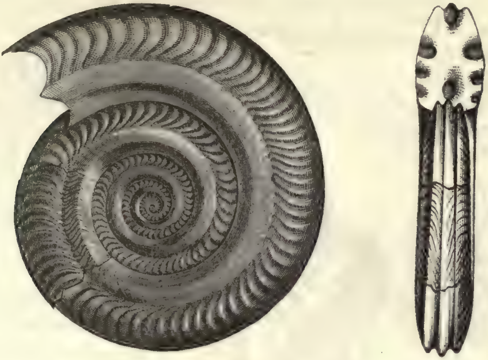

Fig. 236.—*Ammonites bifrons*, from the Lias.

Distribution of the Cephalopoda in Space.—All the *Cephalopoda*, without exception, are marine. Some of the Cuttle-fishes (such as the *Octopi* and *Sepia*) live in the vicinity of land, especially frequenting rocky bottoms; while others (such as *Argonauta*, *Spirula*, *Sepiola*, *Onychoteuthis*, &c.) live in the open sea, often far from land, swimming at or near the surface. Some of the Cuttle-fishes attain a gigantic size; but all these colossal forms of the class appear to belong to the *Decapoda*. The *Architeuthis* of the North Atlantic is certainly known to attain a length of 15 feet or upwards to the body and head, and from 30 to 40 feet or more in the long tentacles. The Pearly Nautilus is confined to the Pacific and Indian Oceans, and appears to be an inhabitant of shallow water.

Distribution of Cephalopoda in Time.—The Cephalopods are largely represented in all the primary groups of stratified rocks from the Upper Cambrian up to the present day. Of the two orders of *Cephalopoda*, the *Tetrabranchiata* is the oldest, attaining its maximum in the Palæozoic period, decreasing in the Mesozoic and Kainozoic epochs, and being represented at the present day by the single form *Nautilus pompilius*, together with some varieties or nearly allied species. Of the sections of this order, the *Nautilidæ* proper and the *Orthoceratidæ* are pre-eminently Palæozoic, and the *Ammonitidæ* are not only pre-eminently, but are almost exclusively, Secondary. Of the abundance of the two former families in the Silurian seas some idea may be obtained when it is mentioned that over a thousand species have been described by M. Barrande from the Silurian basin of Bohemia alone. The *Nautilidæ* proper have gradually decreased in numbers from the Palæozoic through the Secondary and Tertiary periods to the present day. The *Orthoceratidæ* died out much sooner, being exclusively Palæozoic, with the exception of the genera *Orthoceras* itself and *Cyrtoceras*, which survived into the commencement of the Secondary period, finally dying out in the Trias.

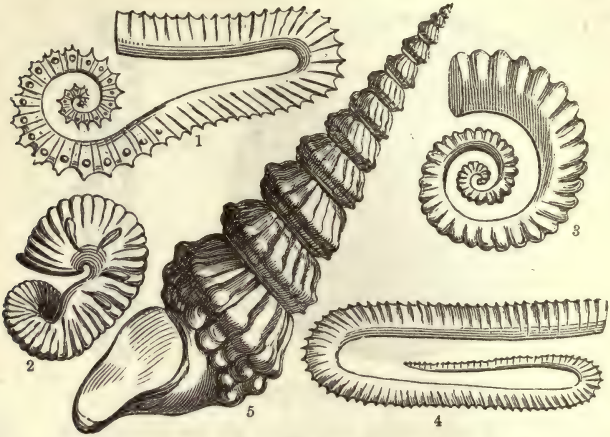

Fig. 237.—Shells of Secondary Cephalopods. 1. *Ancyloceras Matheronianus*; 2. *Scaphites æqualis*; 3. *Crioceras Duvalii*; 4. *Hamites attenuatus*; 5. *Turrilites catenatus*.

The second family of the *Tetrabranchiata*—viz., the *Ammonitidæ*—is almost exclusively Secondary, being very largely represented by numerous species of the genera *Ammonites*, *Ceratites*, *Baculites*, *Turrilites*, &c. The principal Palæozoic genera are *Goniatites* and *Bactrites*, of which the former is found from the Upper Silurian to the Trias, whilst the latter is a Devonian form; but true Ammonites have been found in strata of Carboniferous age in India (Dr Waagen). The genus *Ceratites* is characteristically Triassic, but it is said to occur in the Devonian rocks. All the remaining genera are exclusively Secondary, the genera *Baculites*, *Turrilites*, *Hamites*, and *Ptychoceras* being confined to the Cretaceous period. The only genus which passes up into the Tertiary is *Ammonites*, which occurs in beds believed to be of this age in America.

Of the Dibranchiate Cephalopoda the record is less perfect, as they have few structures which are capable of preservation. They attain their maximum, as fossils, shortly after their first appearance in the Secondary rocks, where they are represented by the large and important family of the *Belemnitidæ*. Some of the *Teuthidæ* and *Sepiadæ* are found both in the Secondary and in the Tertiary rocks, and two species of Argonaut have been discovered in the later Tertiaries. No example of a Dibranchiate Cephalopod is known from the Palæozoic deposits, and the order attains its maximum at the present day.

LITERATURE.

GENERAL.

1. "Manual of the Mollusca." S. P. Woodward. 3d ed., with "Appendix of Recent and Fossil Conchological Discoveries," by Ralph Tate. 1875.
2. "Handbuch der Conchyliologie." Philippi. 1853.
3. "Malacozoa." Bronn and Keferstein. In 'Bronn's Klassen und Ordnungen des Thier-Reichs.' 1862-66.
4. "Genera of Recent Mollusca." H. and A. Adams. 1853-58.
5. "Catalogue of the Mollusca in the British Museum." J. E. Gray.
6. "Figures of Molluscous Animals." Mrs Gray. 1874.
7. "Manuel de Conchyliologie." Chenu. 1859.
8. "Illustrations Conchyliologiques." Chenu. (Begun in 1843.)
9. "Thesaurus Conchyliorum." G. B. Sowerby. (Begun in 1842.)
10. "Conchologia Iconica." Lovell Reeve. (Begun in 1841.)
11. "Treatise on Malacology." Swainson. 1834.
12. "Conchology." Swainson. 1840.
13. "Mémoires pour servir a l'histoire et l'anatomie des Mollusques." Cuvier. 1816.
14. "History of British Mollusca." Forbes and Hanley. 1853.
15. "Manual of British Conchology." Gwyn Jeffreys. 1862-69.
16. "Traité élémentaire de Conchyliologie." Deshayes. 1839-59.
17. "American Conchology." Say. 1830-32.
18. "Synopsis of the Marine Invertebrates of Grand Manan." Stimpson. 1851.
19. "Invertebrata of Vineyard Sound." Smith and Verrill. 1874.
20. "Mineral Conchology of Great Britain." J. Sowerby. 1812-30.
21. "Traité de Paléontologie." Pictet. 1853-57.
22. "Cours élémentaire de Paléontologie." D'Orbigny. 1849-52.
23. "Matériaux pour la Paléontologie Suisse." Pictet. (Begun in 1834.)
24. "Catalogue of British Fossils." Morris. 1854.

POLYZOA.

25. "Catalogue of the Marine Polyzoa in the Collection of the British Museum." Busk. 1852 and 1875.
26. "Monograph of the Fossil Polyzoa of the Crag." Busk. 'Palæontographical Society.' 1859.
27. "Monograph of the Fresh-water Polyzoa." Allman. 'Ray Society.' 1856.
28. "Bryozoa." Ehrenberg. 'Symbolæ physicæ.' 1831.
29. "History of British Zoophytes." Johnston. 2d ed. 1847.
30. "Popular History of British Zoophytes." Landesborough. 1852.
31. "Die Pflanzenthiere in Abbildungen nebst Beschreibungen." Esper. 1788-1830.
32. "Histoire des Coralligènes flexibles." Lamouroux. 1816.
33. "Histoire naturelle du litoral de France." Audouin and Milne-Edwards. 1831-34.
34. "Manual of Marine Zoology." Gosse. 1855.
35. "Fauna of Cornwall." Couch. 1852.
36. "Catalogue of the Zoophytes of Northumberland and Durham." Joshua Alder. 'Trans. Tyneside Naturalists' Field Club.' 1857.
37. "Minute Structure of some of the higher forms of Polypes." A. Farre. 'Phil. Trans.' 1837-38.
38. "On Rhabdopleura, &c." Allman. 'Quart. Journ. Microscopical Science.' 1869.
39. "Om Hafs-bryozoernas utveckling och Fett-Kroppar." Smitt. 'Öfversigt af K. Vetenskaps-Akad. Förhandl.' 1865.
40. "Beiträge zur Anatomie und Entwickelungsgeschichte der Phylactolämen Süsswasserbryozoen." Nitsche. 'Archiv für Anat. und Phys.' 1868.
41. "Beiträge zur Kenntniss der Bryozoen." Nitsche. 'Siebold und Kölliker's Zeitschrift." 1871.
42. "Petrefacta Germaniæ." Goldfuss. 1826-33.
43. "Paléontologie Française" ('Terrains Crétacés et Jurassiques'). D'Orbigny. 1840-53.
44. "Polypiarien des Wiener Tertiär Beckens." Reuss. 1847.
45. "Observations on Polyzoa: Sub-order Phylactolæmata." Alpheus Hyatt. 'Proc. Essex Inst.' 1865.
46. "Recent Progress in our Knowledge of the Structure and Development of the Phylactolæmatous Polyzoa." Allman. 'Journ. Linn. Soc.,' vol. xiv. 1879.
47. "On the Relations of Rhabdopleura." Allman. 'Journ. Linn. Soc.,' vol. xiv. 1879.

TUNICATA.

48. Article "Tunicata." T. Rupert Jones. 'Todd's Cyclopædia of Anatomy and Physiology.' 1848.
49. "Mémoire sur les Ascidies et leur Anatomie." Cuvier. 'Mém. du Museum.' 1815.
50. "Mémoire sur les Animaux sans Vertèbres (Recherches Anatomiques sur les Ascidies Composèes," &c.) Savigny. 1816.
51. "Anatomisk-physiologiske Undersögelser over Salperne." Eschricht. 'Roy. Danish Transactions.' 1841.
52. "Observations sur le Generation et le Developpment des Biphores." Krohn. 'Annales des Science Naturelles.' 1846.

53. "Recherches sur l'Embryogénie, l'Anatomie, et la physiologie des Ascidies simples." Van Beneden. 'Mém. de l'Acad. Roy. de Belgique.' 1847.
54. "Observations sur les Ascidies Composées des Côtes de la Manche." Milne-Edwards. 1844.
55. "Anatomy and Physiology of Salpa and Pyrosoma." Huxley. 'Phil. Trans.' 1851.
56. "Observations on Appendicularia and Doliolum." Huxley. 'Phil. Trans.' 1851.
57. "Die Entwickelungsgeschichte der einfachen Ascidien." Kowalewsky. 'Mém. de l'Acad. Imp. des Sciences de St Petersbourg.' 1866.
58. "Die Stammverwandschaft zwischen Ascidien und Wirbelthiere." Kupffer. 'Schultze's Archiv für Mic. Anat.' 1870.
59. "Zur Entwickelung der einfachen Ascidien." Kupffer. 'Schultze's Archiv,' 1872.
60. "De animalibus quibusdam e classe Vermium." Chamisso. 1819.
61. "Étude critique des travaux d'embryogénie relatifs à la parenté des Vertébrés et des Tuniciers." Giard. 'Lacaze-Duthier's Archives de Zoologie.' 1872.
62. "Entwickelt sich die Larve der einfachen Ascidien in der ersten Zeit nach dem Typus der Wirbelthiere?" Von Baer. 'Mém. de l'Acad. Imp. des Sciences de St Petersbourg.' 1873.
63. "Zur Anatomie des Schwanzes der Ascidien-Larven (Botryllus violaceus)." H. Reichert. 'Abhandl. d. K. Akad. der Wiss. Berlin.' 1875.
64. "Ascidies simples des côtes de France." Lacaze-Duthiers. 'Archives Zool. Exper.' 1874.
65. "On Two new Forms of Deep-sea Ascidians." Moseley. 'Trans. Linn. Soc.' Ser. 2, vol. i. 1877.

BRACHIOPODA.

66. "On the Anatomy of the Brachiopoda." Owen. 'Trans. Zool. Soc.' 1835.
67. "On the Organisation of the Brachiopoda." Hancock. 'Phil. Trans.' 1858.
68. "Anatomy of Brachiopoda." Gratiolet. 'Comptes Rend.,' 1853; and 'Journ. de Conchyliologie,' 1857, 1859, and 1860.
69. "Monograph of the British Fossil Brachiopoda." Thomas Davidson. 'Palæontographical Society.' 1851-71. (The first part contains a Memoir by Prof. Owen on the Anatomy of Terebratula, and one by Dr W. B. Carpenter, on the Intimate Structure of the Shell of the Brachiopoda.)
70. Article "Brachiopoda." Davidson. 'Encyclopædia Britannica,' 9th ed.
71. "Qu'est ce qu'un Brachiopode?" Davidson. 'Ann. de la Soc. Malacologique de Belg.' 1876. (Translated under the name of "What is a Brachiopod?" 'Geol. Mag.' 1877.)
72. "On the Trimerellidæ." Davidson and King. 'Quart. Journ. Geol. Soc.' 1874.
73. "On the Microscopical Structure of Shells." Carpenter. 'Rep. Brit Assoc.' 1844-47.
74. "On the Systematic Position of the Brachiopoda." Morse. 'Proc. Bost. Soc. Nat. Hist.' 1873.

75. "Embryology of Terebratulina." Morse. 'Mem. Bost. Soc. Nat. Hist.' 1873.
76. "Early Stages of Terebratulina septentrionalis." Morse. 'Mem. Bost. Soc. Nat. Hist.,' 1869; and 'Ann. and Mag. Nat. Hist.,' 1871.
77. "Entwickelung der Brachiopoden." Kowalewsky. 'Mém. de l'Acad. Imp. des Sci. de St Petersbourg.' 1874.

LAMELLIBRANCHIATA.

78. Article "Conchifera." Deshayes. 'Todd's Cyclopædia of Anatomy and Physiology.' 1835.
79. "The Pelecypoda of the Cretaceous Rocks of India." Ferdinand Stoliczka. 'Palæontologia Indica.' 1875.
80. "Anatomy of Anodonta cygnea." Rolleston. 'Forms of Animal Life.' 1870.
81. "Observations on the Genus Unio." Lea. 1829-75.
82. "Synopsis of the Family Unionidæ." Lea. 4th ed. 1870.
83. "Structure and Affinities of the Hippuritidæ." S. P. Woodward. 'Quart. Journ. Geol. Soc.' 1854.
84. "Bidrag till Kännedomen om utvecklingen af Mollusca Acephala." Lovén. 'Kongl. Vetenskaps-Akad. Handl. Stockholm.' 1848-50. (Embryology of Lamellibranchs).
85. "Entwickelung von Cyclas." O. Schmidt. 'Müller's Archiv,' 1874.

GASTEROPODA.

86. "Voyage de l'Astrolabe. Zoologie." Quoy et Gainard. 1832-35.
87. "Voyage de la Bonite. Zoologie." Eydoux et Souleyet. 1851-52.
88. "On the Morphology of the Cephalous Mollusca." &c. Huxley. 'Phil. Trans.' 1853.
89. "Das Gebiss der Schnecken zur Begründung einer natürlichen Classification untersucht." Troschel. 1856-76.
90. "Monograph of the British Nudibranchiate Mollusca." Alder and Hancock. 'Ray Society.' 1845-55.
91. "Monographia pneumonopomorum viventium." Pfeiffer. 1852. Supplement. 1858.
92. "Cretaceous Gasteropoda of Southern India." Ferdinand Stoliczka. 'Palæontologia Indica.' 1868.
93. "Manual of the Land and Fresh-water Shells of Great Britain." J. E. Gray. 1857.
94. "Terrestrial Air-breathing Mollusks of the United States." Binney. 1851-57.
95. "Observations on the Development of the Pond-Snail." Ray Lankester. 'Quart. Journ. Microscop. Science.' 1874.
96. "Beiträge zur Entwickelungsgeschichte der Prosobranchiaten." Salensky. 'Siebold und Kölliker's Zeitschrift.' 1872.

PTEROPODA.

97. "Untersuchungen über Pteropoden und Heteropoden." Gegenbaur. 1855.
98. "On the Morphology of the Cephalous Mollusca." (*Pteropoda* and *Heteropoda*). Huxley. 'Phil. Trans.' 1853.
99. Article "Pteropoda." T. Rymer Jones. 'Todd's Cyclopædia of Anat. and Phys.' 1847.

100. "Anatomische Untersuchungen über die *Clione borealis.*" Eschricht. 1848.
101. "Histoire naturelle des Mollusques Ptéropodes." Rang and Souleyet. 1852.
102. "Entwickelungsgeschichte der Pteropoden und Heteropoden." Krohn. 'Müller's Archiv,' 1856-57.
103. "Études sur le Développment des Mollusques." Fol. 'Archives Zool.' 1875.
104. "Ptéropodes Siluriens de la Bohême." Barrande. 1867.

CEPHALOPODA.

105. "Leçons de l'Anatomie Comparée." Cuvier. 1800.
106. "Mémoire sur les Céphalopodes et sur leur Anatomie." Cuvier. 1817.
107. Article "Cephalopoda." Owen. 'Todd's Cyclopædia of Anat. and Phys.' 1836.
108. "Histoire naturelle des Céphalopodes acétabulifères, vivants et fossiles." Ferussac and D'Orbigny. 1835-48.
109. "Mémoire sur l'Argonauta." Van Beneden. 'Nouv. Mém. de l'Acad. Roy. de Bruxelles." 1838.
110. "The Animal of Spirula." J. E. Gray. 'Ann. and Mag. Nat. Hist.' 1845.
111. "Zoology of the Voyage of H.M.S. Samarang." Owen. 1848.
112. "Supplementary Observations on the Anatomy of Spirula australis, Lamarck." Owen. 'Ann. Nat. Hist.' Ser. 5, vol. iii. 1879.
113. "Observations on the Hectocotyli of Tremoctopus violaceus and Argonauta argo." Kölliker. 'Trans. Linn. Soc.' 1846.
114. "Entwickelungsgeschichte der Cephalopoden." Kölliker. 1844.
115. "Development of the Cephalopoda." Ray Lankester. 'Ann. and Mag. Nat. Hist.' 1873; and 'Quart. Journ. Microscop. Sci.,' 1875.
116. "Belemnites from the Oxford Clay." Owen. 'Phil. Trans. 1844.
117. "Structure of Belemnites." Huxley. 'Mem. Geol. Survey.' 1864.
118. "Monograph of the Belemnitidæ." Phillips. 'Palæontographical Society.' 1865-69.
119. "Memoir on the Pearly Nautilus." Owen. 1822.
120. "Bijdrage tot de outleedkundige Kennis aangaende Nautilus pompilius," &c. Van der Hoeven. 1856.
121. "Embryology of the Tetrabranchiates." Hyatt. 'Bulletins of the Museum of Comp. Zoology.' 1872.
122. "Cephalopodes: Études Générales." Barrande. 1877.

VERTEBRATE ANIMALS.

CHAPTER L.

GENERAL CHARACTERS AND DIVISIONS OF THE VERTEBRATA.

THE five sub-kingdoms which we have previously considered—viz., the *Protozoa*, *Cœlenterata*, *Echinodermata*, *Annulosa*, and *Mollusca*—were grouped together by the French naturalist Lamarck to form one great division, which he termed *Invertebrata*, the remaining members of the animal kingdom constituting the division *Vertebrata*. The division *Vertebrata*, though including only a single sub-kingdom, is so compact and well marked a division, and its distinctive characters are so numerous and so important, that this mode of looking at the animal kingdom is, at any rate, a very convenient one.

The sub-kingdom *Vertebrata* may be shortly defined as comprising *animals in which the body is composed of a number of definite segments arranged along a longitudinal axis; the nervous system is in its main masses dorsal, and the neural and hæmal regions of the body are always completely shut off from one another by a partition; the limbs are never more than four in number, and are always turned away from the neural aspect of the body; mostly there is the bony axis known as the "spine" or "vertebral column," and in all the structure known as the "notochord" is present—in the embryo, at any rate.* These characters distinguish the *Vertebrata*, as a whole, from the *Invertebrata;* but it is necessary to define these broad differences more minutely, and to consider others which are of little less importance.

One of the most obvious, as it is one of the most fundamental, of the distinctive characters of *Vertebrates*, is to be found in the shutting off of the main masses of the nervous system from the general cavity of the body. In all *Invertebrate* animals, without exception, the body (fig. 238, A) may be regarded as a *single* tube, enclosing all the viscera; and consequently, in this case, the nervous system is contained within the general cavity of the body, and is not in any way shut off from the alimentary canal. The transverse section, however, of a *Vertebrate* animal exhibits *two* tubes (fig. 238, B), one of which contains the great masses of the nervous system—that is, the cerebro-spinal axis, or brain and spinal cord—whilst the other contains the alimentary canal and the chief circulatory organs, together with certain portions of the nervous system known as the "ganglionic" or "sympathetic" system. Leaving the cerebro-spinal centres out of sight for a moment, we see that the larger or visceral tube of a Vertebrate animal contains the digestive canal, the hæmal system, and a gangliated nervous system. Now this is exactly what is contained in the visceral cavity of any of the higher Invertebrate animals; and the opinion has been generally entertained that it is the sympathetic nervous system of Vertebrates which is truly comparable to, and homologous with, the nervous system of Invertebrates. On the other hand, there are Invertebrates with a sympathetic system of nerves, and the development of the nerve-chain of the *Annulosa* resembles that of the cerebro-spinal axis of the *Vertebrata*.

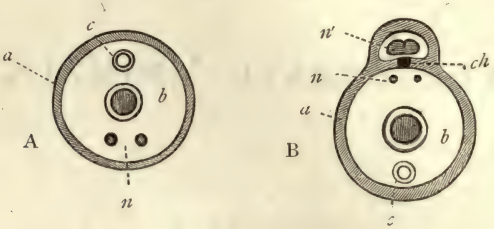

Fig. 238.—A, Transverse section of the body of one of the higher *Invertebrata*: *a* Body-wall; *b* Alimentary canal; *c* Hæmal system; *n* Nervous system. B, Transverse section of the body of a *Vertebrate* animal: *a* Body-wall; *b* Alimentary canal; *c* Hæmal system; *n* Sympathetic system of nerves; *n′* Cerebro-spinal system of nerves; *ch* Notochord.

The tube containing the cerebro-spinal centres is formed as follows: At an early period in the development of the embryo of any Vertebrate animal, the portion of the ovum in which development is going on — the "germinal area" — becomes elevated into two parallel ridges, one on each side of the middle line, enclosing between them a long groove, which is known as the "primitive groove" (fig. 239, A, B). The ridges which bound the primitive groove are known as the "laminæ dorsales;" and they become more and more raised up, till they ultimately meet in the middle line, and unite to form a tube, within which the cerebro-spinal nervous centres are developed. It follows from its mode of formation that the inner wall of the tube formed by the primitive groove, which remains as the septum between the cerebro-spinal canal and the body-cavity, is nothing more than a portion of the primitive wall of the body of the embryo. And there appears to be little doubt, as believed by Remak and Huxley, that the cerebro-spinal nervous centres are "the result of a modification of that serous layer of the germ, which is continuous elsewhere with the epidermis" (Huxley).

Another remarkable peculiarity as regards the nervous system is found in the fact that in no Vertebrate animal does the alimentary canal pierce the main masses of the nervous system, but turns away to open on the opposite side of the body. In most Invertebrates, on the other hand, in which there is a well-developed nervous system, this is perforated by the gullet, so that an œsophageal nerve-collar is formed, and some of the

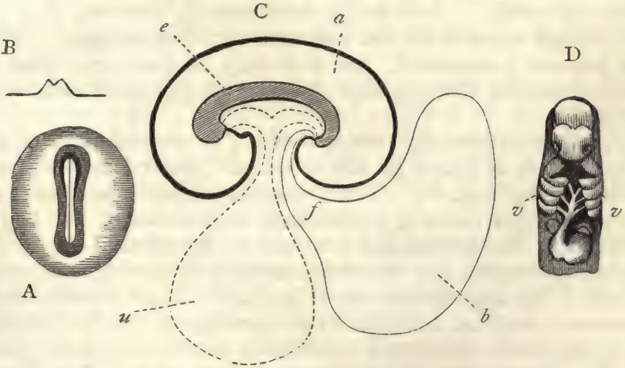

Fig. 239.—Embryology of Vertebrata. A, Portion of the germinal area of the ovum of a Bitch, showing the primitive groove (after Bischoff). B, Profile view of the same. C, Diagram representing the amnion and allantois: *e* Embryo; *a* Amnion; *u* Umbilical vesicle; *b* Allantois; *f* Pedicle of the allantois, afterwards the urinary bladder. D, Head of an embryo, showing the visceral arches (*v v*).

nervous centres become præ-œsophageal, whilst others are post-œsophageal.

Furthermore, the floor of the "primitive groove" in the embryo of all Vertebrates has developed in it at an early period the structure known as the "notochord" or "chorda dorsalis" (fig. 238, B, *ch*). This structure, doubtfully represented in any Invertebrate, is a semi-gelatinous or cartilaginous collection of cells, forming a rod-like axis, which tapers at both ends, and extends along the floor of the cerebro-spinal canal, supporting the cerebro-spinal nervous centres. In some Vertebrates, such as the Lancelet (*Amphioxus*), the notochord is persistent throughout life. In the majority of cases, however, the notochord is replaced before maturity by the structure known as the "vertebral column" or "backbone," from which the sub-kingdom *Vertebrata* originally derived its name. This is not the place for an anatomical description of the spinal column, and it is sufficient to state here that it is essentially composed of a series of cartilaginous, or more or less completely ossified, segments or *vertebræ*, arranged so as to form a longitudinal axis, which protects the great masses of the nervous system. It is to be remembered, however, that all Vertebrate animals do not possess a vertebral column. They all possess a *notochord;* but this may be persistent, and in many cases the development of the spinal column is extremely imperfect.

Another embryonic structure which is characteristic of all Vertebrates, is found in the so-called "visceral arches" and "clefts" (fig. 239, D). The "visceral arches" are a series of parallel ridges running transversely to the axis of the body, situated at the sides of, and posterior to, the mouth. As development proceeds, the intervals between these ridges become grooved by depressions which gradually deepen, until they become converted into a series of openings or "clefts," whereby a free communication is established between the upper part of the alimentary canal (pharynx) and the external medium. In Fishes and many Amphibians the greater number of the visceral clefts remain open throughout life; and the visceral arches of all fishes (except the Lancelet) throw out filamentous or lamellar processes, which receive branches of the aorta and constitute branchiæ. In the higher *Vertebrata* all the visceral clefts become closed, whilst no branchiæ are ever developed upon the visceral arches.

The limbs of Vertebrate animals are always articulated to the body, and they are always turned away from the neural aspect of the body. They may be altogether wanting, or they may be partially undeveloped; but there are never more than two pairs, and they always have an internal skeleton for the attachment of the muscles of the limb.

A specialised blood-vascular or "hæmal" system is present in all the *Vertebrata;* and in all except one—the *Amphioxus*—there is a contractile cavity or *heart*, which never consists of less than two chambers provided with valvular apertures. In all the *Vertebrata* the heart is essentially a *respiratory* heart—that is to say, it is concerned with driving the impure or venous blood to the breathing organs; and in its simplest form (fishes) it is nothing more than this. In the higher Vertebrates, however, there is superadded to this a pair of cavities which are concerned in driving the pure or arterial blood to the body. In the case of the Mammals, these two circulations are often spoken of as the "lesser" or "pulmonary" circulation, and the "greater" or "systemic" circulation.

In all Vertebrates there is that peculiar modification of the venous system which is known as the "hepatic portal system." That is to say, a portion of the blood which is sent to the alimentary canal, instead of returning to the heart by the ordinary veins, is carried to the liver by a special vessel—the *vena portæ*—which ramifies through this organ after the manner of an artery.

In all Vertebrates, also, is found the peculiar system of vessels known as the "lacteal system." This is to be regarded as an appendage of the venous system of blood vessels, and consists of a series of vessels which take up the products of digestion from the alimentary canal, elaborate them, and finally empty their contents into the veins.

Lastly, the masticatory organs of Vertebrates are modified portions of the walls of the head, and never "hard productions of the alimentary mucous membrane, or modified limbs" (Huxley), as they are amongst the Invertebrata.

The above are the leading characters of the *Vertebrata* as a whole; but before going on to consider the primary divisions of the sub-kingdom, it may be as well to give a very brief and general description of the anatomy of the higher and more typical Vertebrates, commencing with their bony framework, or skeleton.

The *skeleton* of the *Vertebrata* may be regarded as consisting essentially of the bones which go to form the head and trunk on the one hand (sometimes called the "axial" skeleton), and of those which form the supports for the limbs ("appendicular" skeleton) on the other hand. The bones of the head and trunk may be looked upon as essentially composed of a series of bony rings or segments, arranged longitudinally, one behind the other. Anteriorly these segments are much expanded, and likewise much modified, to form the bony case which encloses the brain, and which is termed the *cranium* or skull. Behind the head the segments enclose a much smaller cavity, which is called the "neural" or spinal canal, as it encloses the spinal cord; and they are arranged one behind the other, forming the vertebral column. The segments which form the vertebral column are called "vertebræ," and they have the following general structure: Each vertebra (fig. 240, A) consists of a central piece, which is the fundamental and essential element of the vertebra, and is known as the "body" or "centrum" (*c*). From the upper or posterior surface of the centrum spring two bony arches (*n n*), which are called the "neural arches" or "neurapophyses," because they form with the body a canal—the "neural canal"—which encloses the spinal cord. From the point where the neural arches meet behind, there is usually developed a longer or shorter spine, which is termed the "spinous process," or "neural spine" (*s*). From the neural arches there are also developed in the typical vertebra two processes (*a a*), which are known as the "articular" processes, or "zygapophyses." The vertebræ are united to one another partly by these, but to a greater extent by the bodies or "centra." From the sides of the vertebral body, at the point of junction with the neural arches, there proceed two lateral processes (*d d*),

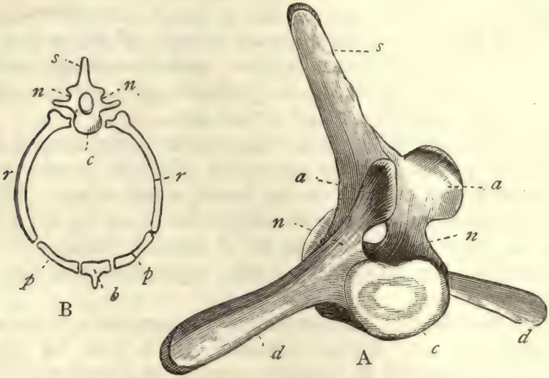

Fig. 240.—A, Lumbar vertebra of a Whale: *c* Body or centrum; *n n* Neural arches; *s* Neural spine; *a a* Articular processes; *d d* Transverse processes. B, Diagram of a thoracic vertebra: *c* Centrum; *n n* Neural arches enclosing the neural canal; *s* Neural spine; *r r* Ribs, assisting in the formation of the hæmal arch; *p p* Costal cartilages; *b* Sternum, with hæmal spine. (After Owen.)

which are known as the "transverse processes." (In the typical vertebra the transverse processes consist each of two pieces, an anterior piece or "parapophysis," and a posterior piece or "diapophysis.") These elements form the *vertebra* of the human anatomist, but the "vertebra" of the transcendental anatomist is completed by a second arch which is placed beneath the body of the vertebra, and which is called the "hæmal" arch, as it includes and protects the main organs of the circulation. This second arch is often only recognisable with great difficulty, as its parts are generally much modified, but a good example may be obtained in the human chest, or in the caudal vertebra of a bony fish.

The hæmal arch in the case of the human thorax (fig. 240, B) is formed by the ribs (*r r*) and the costal cartilages (*p p*), and is completed in front by the breast-bone or sternum (*b*), which in some cases—but not in man—develops a spine (the hæmal spine) which corresponds to the neural spine on the opposite aspect of the vertebra.

It follows from the above, that the typical vertebra consists of a central piece or body from which two arches are given off, one of which protects the great masses of the nervous system, and is therefore said to be "neural;" whilst the other protects the main organs of the circulation, and is therefore said to be "hæmal." The correspondence of the typical bony segment or vertebra with the doubly tubular structure of the body in all Vertebrates is thus too obvious to require to be specially pointed out.

As a general rule, the vertebral column is divisible into a number of distinct regions, of which the following are recognisable in man and in the higher *Vertebrata:* 1. A series of vertebræ which compose the neck, and constitute the "cervical region" of the spine (fig. 241, *n*). 2. A number of vertebræ which usually carry well-developed ribs, and form the "dorsal region" (*d*). 3. A series of vertebræ which form the region of the loins, or "lumbar region" (*l*). 4. A greater or less number of vertebræ which constitute the "sacral region," and are usually amalgamated or "anchylosed" together to form a single bone, the "sacrum." 5. The spinal column is completed by a variable number of vertebræ which constitute the "caudal" region, or tail (*c*).

As regards the *skull* of the *Vertebrata*, it has been thought advisable not to enter into any general details here, partly because the subject is one which can only be properly discussed in a work specially devoted to Human or Comparative Anatomy, and partly because there is still much diversity of opinion as to the exact composition of the skull. There is, however, a very general concurrence of opinion that the skull is composed of a series of separate segments, and this is a point which it is important to remember. By Owen, and by many other competent authorities, these cranial segments are looked upon as being nothing more than so many *vertebræ*, the neural canals of which are greatly expanded to enclose the brain, whilst the hæmal arches are very greatly modified to serve different purposes. This view is not accepted by high

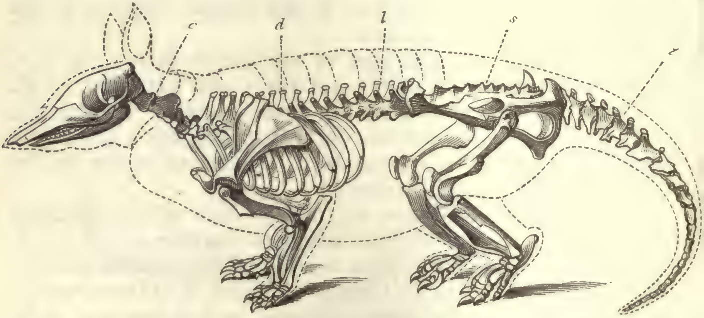

Fig. 241.—Skeleton of an Armadillo, showing the regions of the vertebral column. *c* Cervical region; *d* Dorsal region; *l* Lumbar region; *s* Sacral region; *t* Caudal region or tail.

authorities; but the general fact that the skull is composed of separate segments is universally admitted. The only portion of the bony framework of the head which it is absolutely essential to understand, is the lower jaw or "mandible." The lower jaw is sometimes wanting, but when present, it consists in all *Vertebrata* of two halves or "rami," which are united to one another in front, and articulate separately with the skull behind. In many cases, each half, or "ramus," of the lower jaw consists of several pieces united to one another by sutures; but in the *Mammalia* each ramus consists of no more than a single piece. The two rami are very variously connected with one another, being sometimes only joined by ligaments and muscles, sometimes united by cartilage or by bony suture, and sometimes fused or anchylosed with one another, so as to leave no evidence of their true composition. The mode by which each ramus of the lower jaw articulates with the skull also varies. In the *Mammalia* the lower jaw articulates with a cavity formed on what is known to human anatomists as the temporal bone; but in Birds and Reptiles the lower jaw articulates with the skull, not directly, but by the intervention of a special bone, known as the "quadrate bone" or *os quadratum.*

As regards the *limbs* of Vertebrates, whilst many differences exist, which will be afterwards noticed, there is a general agreement in the parts of which they are composed. As a rule, each pair of limbs is joined to the trunk by means of a series of bones which also correspond to one another in general structure. The fore-limbs, often called the "pectoral" limbs, are united with the trunk by means of a bony arch, which is called the "pectoral" or "scapular" arch; whilst the hind-limbs are similarly connected with the trunk by means of the "pelvic arch." In giving a general description of the parts which compose the limbs and their supporting arches, it will be best to take the case of a Mammal, and the departures from this type will then be readily recognised.

The pectoral or scapular arch consists usually of three bones, the "scapula" or shoulder-blade, the "coracoid," and the "clavicle" or collar-bone; but in the great majority of the Mammals, the coracoid is anchylosed with the scapula, of which it forms a mere process. The scapula or shoulder-blade (fig. 242, *s*) is usually placed outside the ribs, and it forms, either alone or in conjunction with the coracoidal element of the shoulder-girdle, the cavity with which the upper arm is articulated. The coracoid, though rarely existing as a distinct bone in the Mammals, plays a very important part in other Vertebrates, as we shall see hereafter. The clavicles are often wanting or rudimentary, and they are the least essential elements of the scapular arch. The fore-limb proper consists, firstly, of a single bone which forms the upper arm (or "brachium"), and which is known as the *humerus* (*h*). This articulates above with the shoulder-girdle, and is followed below by the fore-arm (or "antibrachium"), which consists of two bones called the *radius* and *ulna*. Of these the *radius* is chiefly concerned with carrying the hand (or "manus"). The

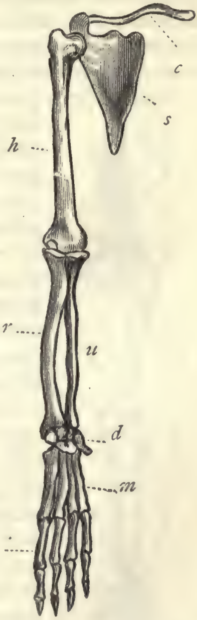

Fig. 242.—Pectoral limb (arm) of Chimpanzee (after Owen). *c* Clavicle; *s* Scapula or shoulder-blade; *h* Humerus; *r* Radius; *u* Ulna; *d* Bones of the wrist, or carpus; *m* Metacarpus; *p* Phalanges of the fingers.

radius and ulna are followed by the bones of the wrist, which are usually composed of several bones, and constitute what is called the *carpus* (*d*). These support the bones of the root of the hand, which vary in number, but are always more or less cylindrical in shape. They constitute what is called the *metacarpus.* The bones of the metacarpus carry the digits, which also vary in number, but are composed each of from two to three cylindrical bones, which are known as the *phalanges* (*p*).

Homologous parts are, as a rule, readibly recognisable in the hind-limb. The pelvic arch, by which the hind-limb is united with the trunk, consists of three pieces—the *ilium*, *ischium*, and *pubes*—which are usually anchylosed together, and form conjointly what is known as the *innominate bone* (fig. 243, *i*). In most Mammals, the two innominate bones unite in front by ligamentous or cartilaginous union, and they constitute, with the sacrum, what is known as the *pelvis.* The hind-limb proper consists of the following parts:—1. The thigh-bone or *femur*, corresponding with the humerus in the fore-limb. 2. The bones of the shank (or "crus"), corresponding with the radius and ulna of the fore-limb, and known as the *tibia* and *fibula.* Of these, the tibia is mainly or altogether concerned in carrying the foot (or "pes"), and it is thus shown to correspond to the radius, whilst the fibula corresponds to the ulna. 3. The small bones of the ankle, known as the *tarsus*, and varying in number in different cases. 4. A variable number of cylindrical bones (normally five), which are called the *metatarsus*, and which correspond to the metacarpus. 5. Lastly, the metatarsus carries the digits, which consist of from two to three small bones or *phalanges*, as in the fore-limb.

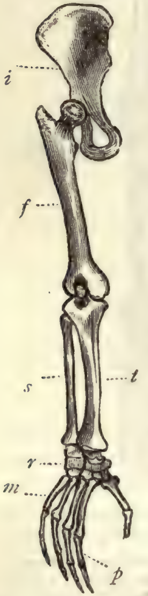

Fig. 243.—Pelvic limb (hind-limb) of Chimpanzee (after Owen). *i* Innominate bone; *f* Femur or thigh-bone; *t* Tibia; *s* Fibula; *r* Tarsus; *m* Metatarsus; *p* Phalanges of the toes.

The *digestive system* of Vertebrates will be spoken of at greater length hereafter; but a brief sketch may be given here of the general phenomena of digestion. All Vertebrate animals are provided with a mouth for the reception of food, and in the great majority of cases the mouth is furnished with *teeth*, which are used sometimes merely to hold the prey, but more commonly to cut and bruise the food, and thus render it capable of digestion. The food is also generally subjected in the mouth to the action of "salivary" glands, the secretion of which serves not only to moisten the food, and thus mechanically assist deglutition, but also to render soluble the starchy elements of the food. The food is next swallowed, or, in other words, is transferred from the mouth to the stomach, this being effected by a complicated arrangement of muscles, whereby the food is forced down the gullet (*œsophagus*) to the proper digestive cavity or stomach. In the stomach (fig. 244, *s*) the food is subjected to two sets of actions; it is mechanically triturated and ground down by the constant contractions of the muscular walls of the stomach; and it is subjected to the chemical action of a special fluid secreted by the stomach, and called the "gastric juice." This fluid has the power of reducing albuminoid substances to a soluble form, and by its action the food is ultimately reduced to a thick acid fluid, called the "chyme." Leaving the stomach by its lower aperture (the *pylorus*), the chyme passes into the intestine, the first portion of which is divided into several sections, but is collectively known as the "small intestine." Here the chyme is subjected to the action of three other digestive fluids; the *bile*, secreted by a special organ, the liver; the *pancreatic juice*, secreted by another gland, the pancreas; and the *intestinal juice*, secreted by certain glands situated in the mucous membrane of the intestine itself. The result of the whole process is that the "chyme" is ultimately converted into a white, alkaline, milky fluid, which is called "chyle." The indigestible portions of the food pass from the small intestine into a tube of larger dimensions, called the "large intestine." Such portions of the food as are still soluble, and capable of being employed in nutrition, are here taken up into the blood, the useless remainder being ultimately expelled by an anal aperture. The last portion of the large intestine is usually less convoluted than the rest, and is called the "rectum."

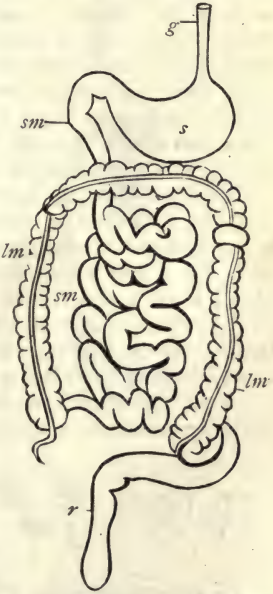

Fig. 244.—Diagram of the digestive system of a Mammal. *g* Gullet; *s* Stomach; *sm* Small intestine; *lm* Large intestine; *r* Rectum, terminating in the aperture of the anus.

The fluid and originally soluble portions of the food, and the chyle which is formed in the process of digestion, are taken into the blood, the losses of which they serve to repair. Part of the nutritive materials of the food is taken up directly by the blood-vessels, and is conveyed by the "vena portæ" to the liver, whence it ultimately reaches the great veins which go to the heart. The greater part, however, of the liquefied food, constituting the chyle, is taken up, not by the blood-vessels, but by a special set of tubes, which form a network in the walls of the intestine, and are known as the "lacteals." In these vessels, and in certain glands which are developed upon them, the chyle undergoes still further elaboration, and is made more similar in composition to the blood itself. All the lacteal vessels ultimately unite into one or more large vessels which open into one of the veins, so that all the chyle is thus finally added to the mass of the circulating blood.

The *blood*, then, or nutrient fluid from which the tissues are built up, is formed in this way out of the materials which are taken into the alimentary canal as food. In all the Vertebrata, with the single exception of the Lancelet (*Amphioxus*), the blood is of a red colour when viewed in mass. This is due to the presence in it of an incredible number of microscopical bodies, which are known as the "blood-corpuscles," the fluid in which these float being itself colourless (fig. 245).

In all the *Vertebrata* the blood is distributed through the body by means of a system of closed tubes, which constitute the "blood-vessels;" and in all except the Lancelet, the means of propulsion are derived from a contractile muscular cavity or "heart," furnished with valvular apertures. In the most complete form of circulation, as seen in Birds and Mammals, the heart is essentially a double organ, composed of two halves, each of which consists of two cavities, an auricle and a ventricle. The right side of the heart is wholly concerned with the "lesser" or pulmonary circulation, whilst the left side is concerned with driving the blood to all parts of the body (systemic circulation). The modifications of the circulatory process will be noticed in speaking of the different classes

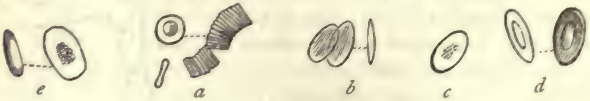

Fig. 245.—Blood-corpuscles of Vertebrata. *a* Red blood-discs of man; *b* Blood-discs of Goose; *c* Crocodile; *d* Frog; *e* Skate.

of Vertebrates, but a brief sketch may be given here of the circulation, in its most complete form, as in a Mammal. In such a case, the venous or impure blood, which has circulated through the body and has parted with its oxygen, is returned by the great veins to the right auricle. From the right auricle (fig. 246, *a*) the blood passes by a valvular aperture into the right ventricle (*v*), whence it is driven through the pulmonary artery to the lungs. The right side of the heart is therefore wholly respiratory in its function. Having been submitted to the action of the lungs, and having given off carbonic acid and taken up oxygen, the blood now becomes arterial, and is returned by the pulmonary veins to the left auricle (*a′*), From the left auricle the aerated blood passes through a valvular aperture into the left ventricle (*v′*), whence it is propelled to all parts of the body by means of a great systemic vessel, the "aorta." The left side of the heart is therefore wholly occupied in carrying out the "greater" or systemic circulation.

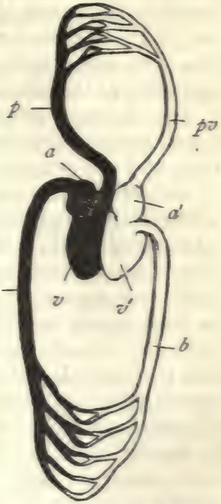

Fig. 246.—Diagram of the circulation of a Mammal. The venous system is marked black; the arterial system is left white. *a* Right auricle; *v* Right ventricle; *p* Pulmonary artery, carrying venous blood to the lungs; *pv* Pulmonary veins, carrying arterial blood from the lungs; *a′* Left auricle; *v′* Left ventricle; *b* Aorta, carrying arterial blood to the body; *c* Vena cava, carrying venous blood to the heart.

The purification of the blood is carried out in all Vertebrates by means of distinct respiratory organs, assisted to a greater or less extent by the skin. In the Fishes, and in the Amphibians to some extent, the process of respiration is carried on by means of *branchiæ* or gills — that is, by organs adapted for breathing air dissolved in water. These are therefore often spoken of as "Branchiate" Vertebrates; but the Amphibians always develop true lungs in the later stages of their existence. In the Reptiles, Birds, and Mammals, branchiæ are never developed, and the respiration is always carried on by means of true lungs—that is, by organs adapted for breathing air directly. These are therefore often spoken of as the "Abranchiate" Vertebrates.

The waste substances of the body—of which the most important are water, carbonic acid, and urea—are got rid of by the skin, lungs, and kidneys. Under ordinary circumstances, the lungs are mainly occupied with the excretion of carbonic acid and watery vapour. The skin chiefly gets rid of superfluous moisture, but can also in many animals excrete carbonic acid as well. The kidneys are present in almost all Vertebrate animals, and their function is mainly to excrete water, and the nitrogenous substance known as urea. In the majority of cases the fluid excreted by the kidneys is conveyed to the exterior by means of two tubes known as the ureters, which empty themselves into a common receptacle, the urinary bladder. In some cases, however, the ureters open into the termination of the alimentary canal (rectum).

The nervous system of Vertebrate animals usually exhibits a well-marked division into two parts—the cerebro-spinal system, and the sympathetic system. The cerebro-spinal system of nerves constitutes the great mass of the nervous system of Vertebrates, and usually exhibits a well-marked separation into spinal cord (*myelon*) and brain (*encephalon*). The proportion borne by the brain to the spinal cord differs much in different cases; and in the Lancelet a brain can hardly be said to be present at all. As already said, the brain and spinal cord are always completely shut off from the visceral cavity, and they are placed upon the dorsal surface of the body. The nerves given off from the cerebro-spinal axis are symmetrically disposed on the two sides of the body, and they are mainly concerned with the functions of "animal" life—that is to say, with sensation and locomotion. The sympathetic system of nerves is unsymmetrically disposed to a greater or less extent, and presides mainly over the functions of "organic" or "vegetative" life, being chiefly concerned with regulating the functions of digestion and respiration, and the circulation of the blood. In its most fully developed form it consists of a double gangliated cord placed in the visceral cavity on the under surface of the spine, and of a series of nervous ganglia, united by nervous cords, and scattered chiefly over the great viscera of the thorax and abdomen.

The organs of the senses are well developed in the *Vertebrata*, and those appropriated to the senses of *sight*, *hearing*, *smell*, and *taste* are protected within bony cavities of the head. The perfection of the senses differs much in different cases, but they are probably never wholly wanting in any Vertebrate animal. There are cases in which vision must be of the most rudimentary character; but even in these cases it is probable that there is a perception of light, even if there is no power of distinguishing objects. The only cases in which it would appear that vision is really altogether absent, are those of animals placed under the wholly abnormal condition of spending their existence in darkness (such as the *Proteus anguinus* of the caves of Illyria). Smell, hearing, and taste are probably rarely, if ever, altogether absent in Vertebrates; though in many cases their organs are very rudimentary. Touch, or "tactile sensibility," is usually possessed to a greater or less degree by the entire surface of the body; but the sense of touch is generally localised in certain particular parts, such as the appendages of the mouth, the lips, the tongue, or the digits.

In all *Vertebrata* without exception reproduction is carried on by means of the sexes, and in all (except in some of the *Serranidæ* among the Fishes) the sexes are in different individuals. No vertebrate animal possesses the power of reproducing itself by fission or gemmation; and in no case are composite organisms or colonies produced. Most of the Vertebrates are *oviparous*—that is to say, the *ova* are expelled from the body of the parent either before or very shortly after impregnation. In other cases, the eggs are retained within the body of the parent until the young are hatched, but no direct connection is formed between the fœtus and the mother, and in these cases the animals are said to be *ovo-viviparous.* In other cases, again, not only is the egg hatched within the parent, but the embryo is retained within the body of the mother, from whom it receives nourishment by direct vascular connection, until its development has been carried out to a greater or less extent; and these animals are said to be *viviparous.*

Many vertebrate animals possess an *exoskeleton*, formed by a hardening of one or other layer of the integument. The integument is composed of two layers—an external non-vascular "epidermis," and a deeper vascular "dermis"—and the exoskeleton may be formed by the deposition of horny matter, or of salts of lime, in either or in both of these. The epidermal exoskeleton is always horny, and, when present, is generally in the form of hairs (*Mammalia*), feathers (Birds), scales (serpents and many lizards), or plates (Chelonians). The horny sheaths of the jaws in Birds and some Reptiles, the outer covering of the horns in some Mammals, the hoofs, claws, and nails of *Mammalia*, are likewise epidermic. The dermal exoskeleton may be either horny or bony; and good examples of it are to be found in the scales of fishes, the bony scutes of the Crocodiles, and the armour-plates of the Armadillos.

DIVISIONS OF THE VERTEBRATA.—The sub-kingdom *Vertebrata* is divided into the five great classes of the Fishes (*Pisces*), Amphibians (*Amphibia*), Reptiles (*Reptilia*), Birds

(*Aves*), and Mammals (*Mammalia*). So far there is perfect unanimity; but when it is inquired into what larger sections the Vertebrata may be divided there is much difference of opinion. Here, the divisions proposed by Professor Huxley will be adopted; but it is necessary that those employed by other writers should be mentioned and explained.

One of the commonest methods of classifying the *Vertebrata* is to divide them into the two primary sections of the *Branchiata* and *Abranchiata*. Of these, the Branchiate section includes the Fishes and Amphibians, and is characterised by the fact that the animal is always provided at some period of its life with branchiæ or gills. The Abranchiate section includes the Reptiles, Birds, and Mammals, and is characterised by the fact that the animal is never provided at any time of its life with gills. Additional characters of the Branchiate Vertebrates are, that the embryo is not furnished with the structures known as the *amnion* and *allantoïs*. Hence the Branchiate Vertebrates are often spoken of as the *Anamniota* and as the *Anallantoidea*. In the Abranchiate Vertebrates, on the other hand, the embryo is always provided with an amnion and allantois, and hence this section is spoken of as the *Amniota* or as the *Allantoidea*.*

By Professor Owen the *Vertebrata* are divided into the two primary sections of the *Hæmatocrya* and the *Hæmatotherma*, the characters of the blood being taken as the distinctive character. The *Hæmatocrya* or Cold-blooded Vertebrates comprise the Fishes, Amphibia, and Reptiles, and are characterised by their cold blood and imperfect circulation. The *Hæmatotherma* or Warm-blooded Vertebrates comprise the Birds and the Mammals, and are characterised by their hot blood, four-chambered heart, and complete separation of the pulmonary and systemic circulations. The chief objection to this division lies in the separation which is effected between the Reptiles and the Birds, two classes which are certainly very nearly allied to one another.

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* The *amnion* (fig. 239, C) is a membranous sac, containing a fluid—the liquor amnii—and completely enveloping the embryo. It constitutes one of the so-called "fœtal membranes," and is thrown off at birth. The *allantois* (fig. 239, C) is an embryonic structure, which is developed out of the middle or "vascular" layer of the germinal membrane. It appears at first as a solid, pear-shaped, cellular mass, arising from the under part of the body of the embryo. In the process of development, the allantois increases largely in size, and becomes converted into a vesicle which envelops the embryo in part or wholly. It is abundantly supplied with blood, and is the organ whereby the blood of the fœtus is aerated. The part of the allantois which is external to the body of the embryo is cast off at birth; but the portion which is within the body is retained, and is converted into the urinary bladder.

By Professor Huxley the *Vertebrata* are divided into the following three primary sections:—

I. ICHTHYOPSIDA.—This section comprises the Fishes and the Amphibians, and is characterised by the presence at some period of life of gills or branchiæ, the absence of an amnion, the absence or rudimentary condition of the allantois, and the possession of nucleated red blood-corpuscles.

II. SAUROPSIDA.—This section comprises the Birds and the Reptiles, and is characterised by the constant absence of gills, the possession of an amnion and allantois, the articulation of the skull with the vertebral column by a single occipital condyle; the composition of each ramus of the lower jaw of several pieces, and the articulation of the lower jaw with the skull by the intervention of an "os quadratum;" and, lastly, the possession of nucleated red blood-corpuscles.

III. MAMMALIA.—This section includes the single class of the Mammals, and agrees with the preceding in never possessing gills, and in having an amnion and allantois. The *Mammalia*, however, differ from the *Sauropsida* in the fact that the skull articulates with the vertebral column by two occipital condyles; each ramus of the lower jaw is simple, composed of a single piece, and the lower jaw is united with the temporal (squamosal) element of the skull, and is not articulated to a quadrate bone. There are special glands — the mammary glands — for the nourishment of the young for a longer or shorter period after birth, and the red blood-corpuscles are non-nucleated.

LITERATURE.

1. "Comparative Anatomy and Physiology of Vertebrates." Owen. 1866-68.
2. "Manual of the Anatomy of Vertebrated Animals." Huxley. 1872.
3. "Principles of Comparative Physiology." W. B. Carpenter.
4. "Forms of Animal Life." Rolleston. 1870.
5. "General Outline of the Organisation of the Animal Kingdom." Rymer Jones. 1871.
6. "Handbook of Zoology." Van der Hoeven. Trans. by Dr W. Clarke. 1856-58.
7. "Manual of Comparative Anatomy." Blumenbach. Trans. by Laurence. 1827.
8. "Comparative Anatomy of Vertebrate Animals." Wagner. Trans. by Tulk. 1845.
9. "Grundriss der Vergleichenden Anatomie." Gegenbaur. 1874.
10. "Le Règne Animal distribué d'après son organisation." Cuvier.
11. "Leçons d'anatomie comparée." Cuvier.

12. "System der Vergleichenden Anatomie." Meckel. 1821-33.
13. "Leçons sur la physiologie et l'anatomie comparée de l'homme et des animaux." Milne-Edwards. 1857-72.
14. "Lectures on the Elements of Comparative Anatomy." (On the Classification of Animals and on the Vertebrate Skull.) Huxley. 1864.
15. "Discourse on the Nature of Limbs." Owen. 1849.
16. "On the Shoulder-Girdle and Sternum." Parker. 'Ray Society.' 1868.
17. "Lectures on Histology." Quekett. 1852-54.
18. "The Microscope and its Revelations." Carpenter.
19. "How to work with the Microscope." Beale.
20. "Lehrbuch der Histologie des Menschen und der Thiere." Leydig. 1857.
21. "Embryology, with the Physiology of Generation." Müller. Trans. by Baly. 1848.
22. "Elements of Embryology." Foster and Balfour. 1876.
23. "The Geographical Distribution of Animals." Alfred Wallace. 1876.
24. "Recherches sur les ossemens fossiles." Cuvier. 1834-36.
25. "Manual of Palæontology." Owen. 1861.
26. "Traité de Paléontologie." Pictet. 1853.
27. "Cours élémentaire de Paléontologie." D'Orbigny. 1849.
28. "Manual of Palæontology." Nicholson. 2d ed. 1879.
29. "Generelle Morphologie der Organismen." Hæckel. 1866.
30. "System der thierischen Morphologie." Victor Carus. 1853.
31. "Entwickelungsgeschichte der Thiere." Von Baer. 1837.
32. "The Morphology of the Skull." Parker & Bettany. 1877.
33. "Lessons in Elementary Anatomy." St George Mivart. 1873.

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DIVISION I.—ICHTHYOPSIDA.

CHAPTER LI.

CLASS I.—PISCES.

THE first class of the *Vertebrata* is that of the Fishes (*Pisces*), which may be broadly defined as including *Vertebrate animals which are provided with gills throughout the whole of life; the heart, when present, consists* (except in *Dipnoi*) *of a single auricle and a single ventricle; the blood is cold; the limbs, when present, are in the form of fins, or expansions of the integument; and there is neither an amnion nor allantois in the embryo, unless the latter is represented by the urinary bladder.*

In form, Fishes are adapted for rapid locomotion in water, the shape of the body being such as to give rise to the least possible friction in swimming. To this end also, as well as for purposes of defence, the body is usually enveloped with a coating of scales developed in the inferior or dermal layer of the skin; whereas the epidermis is represented only by the slimy mucus covering the exterior of the animal. The more important modifications in the form of these dermal scales are as follows: I. *Cycloid* scales (fig. 247, *a*), consisting of thin, flexible, horny or bony scales, circular or elliptical in shape, and having a more or less completely smooth outline. These are the scales which are characteristic of the most of the ordinary bony fishes. II. *Ctenoid* scales (fig. 247, *b*), also consisting of thin horny plates, but

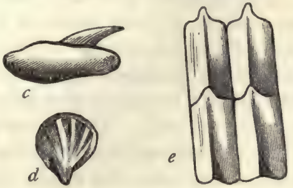

Fig. 247.—Scales of different fishes. *a* Cycloid scale (Pike); *b* Ctenoid scale (Perch); *c* Placoid scale (Thornback); *d* Placoid scale of *Rhina*; *e* Ganoid scales (*Palæoniscus*).

having their posterior margins fringed with spines, or cut into comb-like projections. III. *Ganoid* scales, composed of an inferior layer of bone, covered by a superficial layer of hard polished enamel (the so-called "ganoine"). These scales (fig. 247, *e*) are usually much larger and thicker than the ordinary scales, and though they are often articulated to one another by special processes, they only rarely overlap. IV. *Placoid* scales, consisting of detached bony or dentinal grains, tubercles, or plates, of which the latter are not uncommonly armed with spines (fig. 247, *c* and *d*).

In most fishes there is also to be observed a line of peculiar scales, forming what is called the "lateral line." Each of the scales in this line is perforated by a tube leading down to a longitudinal canal which runs along the side of the body, and is connected with cavities in the head. The function of this singular system has been ordinarily believed to be that of secreting the mucus with which the surface of the body is covered; but this is certainly erroneous, and it seems to be more probably sensory in function, and to be connected with the sense of touch.

As regards their true osseous system or endoskeleton, Fishes vary very widely. In the Lancelet there can hardly be said to be any skeleton, the spinal cord being simply supported by the gelatinous notochord, which persists throughout life. In others the skeleton remains permanently cartilaginous; in others it is partially cartilaginous and partially ossified; and, lastly, in most modern fishes it is entirely ossified, or converted into bone.* Taking a bony fish (fig. 248) as in this respect a typical example of the class, the following are the chief points in the osteology of a fish which require notice:—

The *vertebral column* in a bony fish consists of vertebræ, which are hollow at both ends, or biconcave, and are technically said to be "amphicœlous." The cup-like margins of the vertebral bodies are united by ligaments, and the cavities formed between contiguous vertebræ are filled with the gelatinous remains of the notochord. This elastic gelatinous substance acts as a kind of ball-and-socket joint between the bodies of the vertebræ, thus giving the whole spine the extreme mobility which is requisite for animals living in a watery medium. The ossification of the vertebræ is often much more imperfect than the above, but in no case except that of the Bony Pike (*Lepidosteus*) is ossification carried to a greater extent than this. In this fish, however, the vertebral column is composed of "opisthocœlous" vertebræ—that is, of vertebræ, the bodies of which are concave behind and convex in front. The entire spinal column is divisible into not more than two distinct regions, an *abdominal* and a *caudal region.* The abdominal vertebræ possess a superior or neural arch (through which passes the spinal cord), a superior spinous process (neural spine), and two transverse processes to which the ribs are usually attached. The caudal vertebræ (fig. 248) have no marked transverse processes; but, in addition to the neural arches and spines, they give off an inferior or *hæmal* arch below the body of the vertebræ, and the hæmal arches carry inferior spinous processes (hæmal spines).

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* The so-called "bone" of the skeleton of Fishes is only occasionally true osseous tissue. In a great many instances it is a homogeneous or tubular, bone-like substance, or it may resemble genuine dentine.

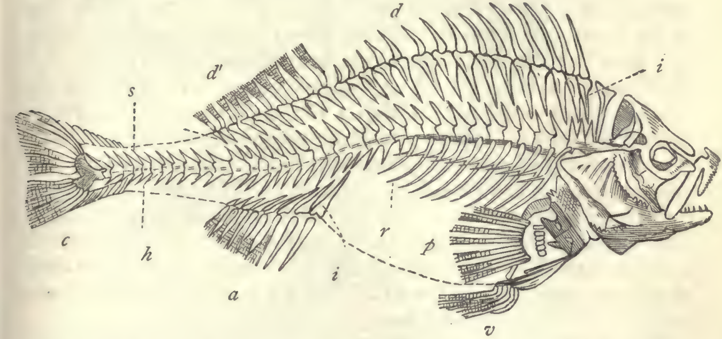

Fig. 248.—Skeleton of the common Perch (*Perca fluviatilis*). *p* One of the pectoral fins; *v* One of the ventral fins; *a* Anal fin, supported upon interspinous bones (*i*); *c* Caudal fin; *d* First dorsal fin; *d'* Second dorsal fin, both supported upon interspinous bones; *i i* Interspinous bones; *r* Ribs; *s* Spinous processes of vertebræ; *h* Hæmal processes of vertebræ.

The *ribs* of a bony fish are attached to the transverse processes, or to the bodies of the abdominal vertebræ, in the form of slender curved bones which articulate with no more than one vertebra each, and that only at a single point. Unlike the ribs of the higher Vertebrates, the ribs do not enclose a thoracic cavity, but are simply embedded in the muscles which bound the abdomen. Usually each rib gives off a spine-like bone, which is directed backwards amongst the muscles. Inferiorly the extremities of the ribs are free, or are rarely united to dermal ossifications in the middle line of the abdomen; but there is never any breast-bone or *sternum* properly so called.

The only remaining bones connected with the skeleton of the trunk are the so-called *interspinous bones* (fig. 248, *i i*).

These form a series of dagger-shaped bones, plunged in the middle line of the body between the great lateral muscles which make up the greater part of the body of a fish. The internal ends or points of the interspinous bones are attached by ligament to the spinous processes of the vertebræ; whilst to their outer ends are articulated the "rays" of the so-called "median" fins, which will be hereafter described. As a rule, there is only one interspinous bone to each spinous process, but in the Flat-fishes (Sole, Turbot, &c.) there are two.

Besides the fins which represent the limbs (pectoral and ventral fins), fishes possess other fins placed in the middle line of the body, and all of these alike are supported by bony spines or "rays," which are of two kinds, termed respectively "spinous rays" and "soft rays." The "spinous rays" are simple bony spines, apparently composed of a single piece each, but really consisting of two halves firmly united along the middle line. The "soft rays" are composed of several slender spines proceeding from a common base, and all divided transversely into numerous short pieces. The soft rays occur in many fishes in different fins, but they are invariably found in the caudal fin or tail (fig. 248, *c*). The rays of the median fins, whatever their character may be, always articulate by a hinge-joint with the heads of the interspinous bones.

The *skull* of the bony fishes is an extremely complicated structure, and it is impossible to enter into its composition here. The only portions of the skull which require special mention are the bones which form the gill-cover or operculum, and the hyoid bone with its appendages. For reasons connected with the respiratory process in fishes, as will be afterwards seen, there generally exists between the head and the scapular arch a great cavity or gap on each side, within which are contained the branchiæ. The cavity thus formed opens externally on each side of the neck by a single vertical fissure or "gill-slit," closed by a broad flap, called the "gill-cover" or "operculum," and by a membrane termed the "branchiostegal membrane."

The gill-cover (fig. 249, *p*, *o*, *s*, *i*) is composed of a chain of broad flat bones, termed the opercular bones. Of these, the innermost articulates with the skull (tympano-mandibular arch), and is called the "præ-operculum;" the next is a large bone called the "operculum" proper; and the remaining two bones, called respectively the "sub-operculum" and "inter-operculum," form, with the operculum proper, the edge of the gill-cover. These various bones are united together by membrane, and they form collectively a kind of movable door, by means of which the branchial chamber can be alternately opened and shut. Besides the gill-cover, however, the branchial chamber is closed by a membrane called the "branchiostegal membrane," which is attached to the os hyoides. The membrane is supported and spread out by a number of slender curved spines, which are attached to the lateral branches of the hyoid bone, act very much as the ribs of an umbrella, and are known as the "branchiostegal rays" (fig. 249, *d*).

The hyoid arch of fishes is attached to the temporal bones of the skull by means of two slender styliform bones, which correspond to the styloid processes of man, and are called the "stylohyal" bones (fig. 250, *f*). The rest of the hyoid arch is composed of a central portion and two lateral branches. Each branch is composed of the following parts: 1. A triangular bone attached above to the stylohyal, and termed the "epihyal bone" (fig. 250, *e*); 2. A much longer bone, known as the "ceratohyal" (*d*). The central portion of the hyoid arch is made up of two small polyhedral bones—the "basihyals" (*b*). From the basihyal there extends *forwards* in many fishes a slender bone, which supports the tongue, and is termed the "glossohyal" or "lingual" (*a*). There is also another compressed bone which extends *backwards* from the basihyals, and which is known as the "urohyal bone" (*c*). This last-mentioned bone is of importance, as it often extends backwards to the point of union of the coracoid bones, and thus forms the isthmus which separates the two branchial apertures.

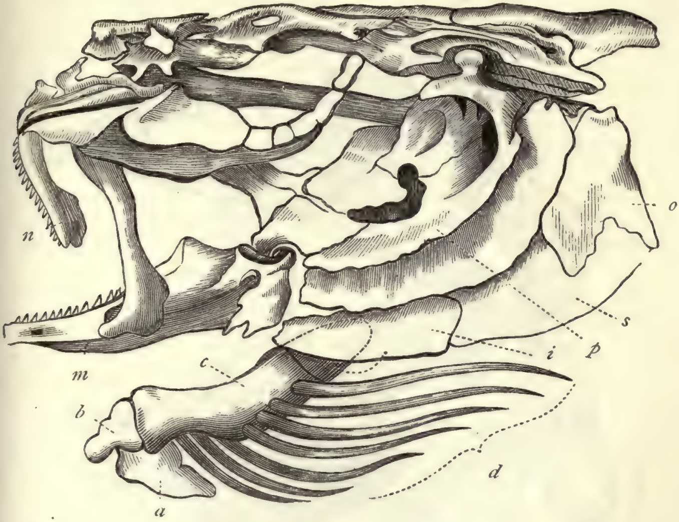

Fig. 249.—Skull of Cod (*Morrhua vulgaris*)—Cuvier. *a* Urohyal; *b* Basihyal; *c* Ceratohyal; *d* Branchiostegal rays; *p* Præ-operculum; *o* Operculum proper; *s* Sub-operculum; *i* Inter-operculum; *m* Mandible; *n* Inter-maxillary bone.

From the outer margins of the epihyal and ceratohyal bones on each side arise the slender curved "branchiostegal rays," which have been previously mentioned. There are usually seven of these on each side. Above the urohyal, and attached in front to the body of the os hyoides, is a chain of bones, placed one behind the other, and termed by Owen the "basibranchial bones." Springing from these are four bony arches—the "branchial arches"—which proceed upwards to be connected superiorly by ligament with the under surface of the skull. The branchial arches—as will be subsequently described—carry the branchiæ, and each is composed of two main pieces, termed respectively the "cerato-branchial" and "epibranchial" bones. The second and third arches are connected with the skull by the intervention of two small bones, often called the "superior pharyngeal bones," but termed by Owen the "pharyngo-branchial" bones.

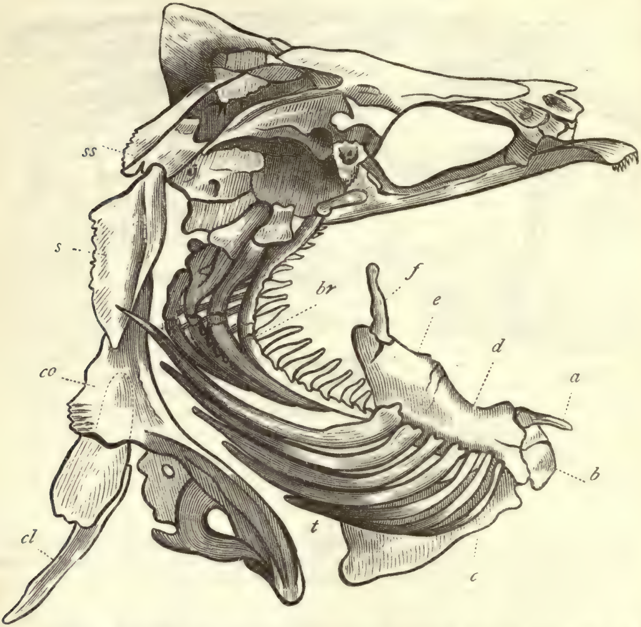

Fig. 250.—Os hyoides, branchiostegal rays, and scapular arch of the Perch (after Cuvier). *ss* Supra-scapula; *s* Scapula; *co* Coracoid; *cl* Supposed representative of the clavicle; *a* Glossohyal bone; *b* Basihyal; *c* Urohyal; *d* Ceratohyal; *e* Epihyal; *f* Stylohyal; *br* Branchial arches; *t* Branchiostegal rays.

The *limbs* of fishes depart considerably from the typical form exhibited in the higher Vertebrates. One or both pairs of limbs may be wanting, but when present the limbs are almost always in the form of *fins*—that is, of expansions of the integument strengthened by bony or cartilaginous fin-rays. The anterior limbs are known as the *pectoral* fins, and the posterior as the *ventral* fins; and they are at once distinguished from the so-called "median" fins by being always disposed in pairs, usually symmetrically. Hence they are often spoken of as the *paired* fins.

The scapular arch (figs. 250, 251) supporting the pectoral limbs is usually joined to the skull (occipital bone), and consists of the following pieces on each side: 1. The supra-scapula (*ss*); 2. The scapula (*s*), articulating with the former; and, 3. The coracoid (*co*), attached above with the scapula, and united below, by ligament or suture, with the coracoid of the opposite side, thus completing the pectoral arch. Lastly, there is often another bone, sometimes single, but oftener of two pieces, attached to the upper end of the coracoid, and this is believed to represent the collar-bone or clavicle.*

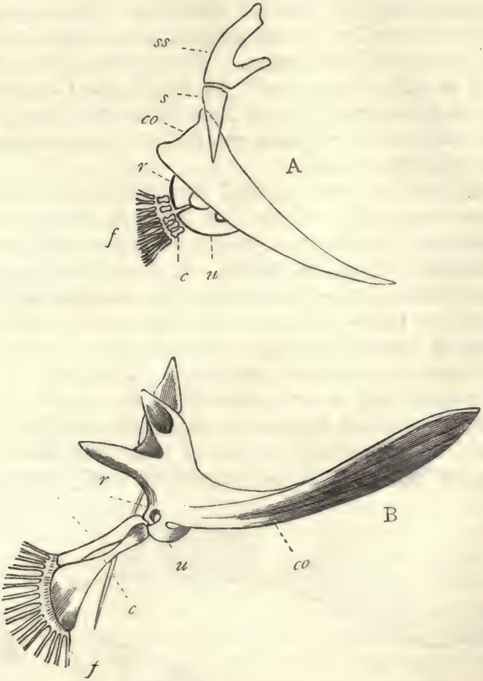

Fig. 251.—Pectoral limbs of Fishes (after Owen). A, Cod (*Morrhua vulgaris*): B, Angler (*Lophius*). *ss* Supra-scapula; *s* Scapula; *co* Coracoid; *r* Radius; *u* Ulna; *cc* Carpal bones; *f* Fin-rays, representing the metacarpus and phalanges of the fingers.

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* These are the views entertained by Owen as to the composition and nature of the pectoral arch of fishes; but they are dissented from by Mr Parker, one of the greatest living authorities on this subject.

The fore-limb possesses in a modified form most of the bones which are present in the higher *Vertebrata*. The *humerus*, or bone of the upper arm, is usually wanting, or it is altogether rudimentary. A radius and ulna (fig. 251, *r*, *u*) are usually present, and are followed by a variable number of bones, which represent the carpus, and some of which sometimes articulate directly with the coracoid. The carpus is followed by the "rays" of the fin proper, these representing the metacarpal bones and phalanges. The pectoral fins vary much in size and in other characters. In the Flying Gurnard (*Dactylopterus*), and the true Flying Fish (*Exocœtus*), the pectorals are enormously developed, and enable the fish to take extensive leaps out of the water.

The hind-limbs or "ventral fins" are wanting in many fishes, and they are less developed and less fixed in position than are the pectoral fins. In the ventral fins no representatives of the tarsus, tibia and fibula, or femur, are ever developed. The rays of the ventral fins—representing the metatarsus and the phalanges of the toes—unite directly with a pelvic arch, which is composed of two sub-triangular bones, united in the middle line and believed to represent the *ischia*. The imperfect pelvic arch, thus constituted, is never united to the vertebral column in any fish. In those fishes in which the ventral fins are "abdominal" in position (*i. e.*, placed near the hinder end of the body) the pelvic arch is suspended freely amongst the muscles. In those in which the ventral fins are "thoracic" or "jugular" (*i. e.*, placed beneath the pectoral fins, or on the sides of the neck), the pelvic arch is attached to the coracoid

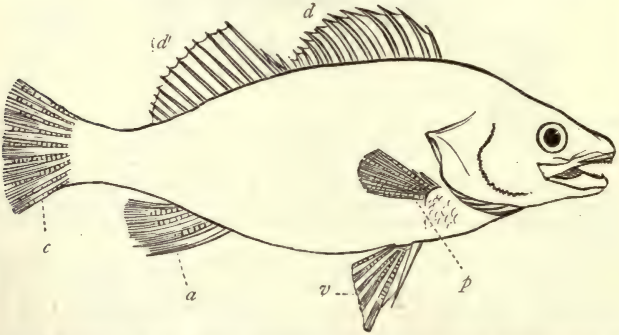

Fig. 252.—Outline of a fish (*Perca granulata*), showing the paired and unpaired fins. *p* One of the pectoral fins; *v* One of the ventral fins; *d* First dorsal fin; *d′* Second dorsal fin; *a* Anal fin; *c* Caudal fin.

bones of the scapular arch, and is therefore wholly removed from its proper vertebra.

In addition to the pectoral and ventral fins—the homologues of the limbs—which may be wanting, fishes are furnished with certain other expansions of the integument, which are "median" in position, and must on no account be confounded with the true "paired" fins. These median fins are variable in number, and in some cases there is but a single fringe running round the posterior extremity of the body. In all cases, however, the median fins are "azygous"—that is to say, they occupy the middle line of the body, and are not symmetrically disposed in pairs. Most commonly, the median fins consist of one, two, or three expansions of the dorsal integument, called the "dorsal fins" (fig. 252, *d*, *d'*); one or two on the ventral surface near the anus—the "anal fins" (fig. 252, *a*); and a broad fin at the extremity of the vertebral column, called the "caudal fin" or tail (*c*). In all cases, the rays which support the median fins are articulated with the so-called interspinous bones, which have been previously described. Though called "median," from their position in the middle line of the body, and from their being unpaired, the median fins of fishes, as shown by Goodsir and Humphry, are truly to be regarded as formed by the coalescence of two lateral elements in the mesial plane of the body.

The caudal fin, or tail, of fishes is always set vertically at the extremity of the spine, so as to work from side to side, and it is the chief organ of progression in the fishes. In its vertical position, and in the possession of fin-rays, it differs altogether from the horizontal integumentary expansion which constitutes the tail of the Whales, Dolphin, and *Sirenia* (Dugong and Manatee). In the form of the tail, fishes exhibit some striking differences. In some of the Bony Fishes and Ganoids, the caudal extremity of the spine is not bent upwards, but divides the caudal fin-rays into two nearly equal portions, and the symmetrical tail-fin thus produced is said to be "diphycercal." In the great majority of the Bony Fishes the tail-fin appears on inspection to be divided into two equal lobes, and it is then said to be "homocercal" (fig. 253, A). This apparent symmetry is due to the fact that the spinal column seems to terminate in the centre of a triangular bony mass, to the free edges of which the fin-rays are symmetrically attached. In reality, however, the unossified notochord is prolonged into the upper lobe of the tail; and as there is a much larger number of fin-rays below the bent-up notochord than above it, the tail is truly unsymmetrical in its fundamental structure. Lastly, in the *Elasmobranchii*, and most Ganoids, the tail is conspicuously unsymmetrical (fig. 253, B), and is then said to be

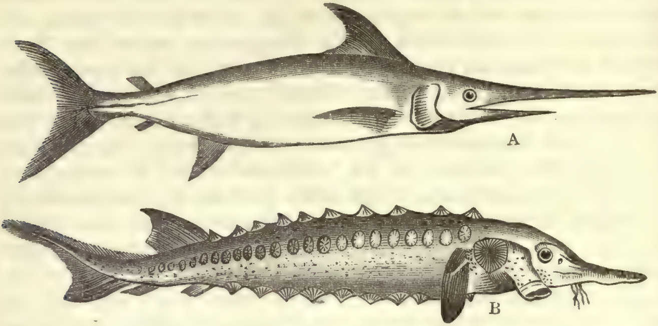

Fig. 253.—A, Sword-fish, showing homocercal tail; B, Sturgeon, showing the heterocercal form of tail.

"heterocercal." In these cases, the lower lobe of the tail is conspicuously larger than the upper, owing to the disproportionate development of the hæmal rays; and the spinal column is prolonged into the upper lobe of the tail.

In a recently published and important memoir, Professor A. Agassiz has shown that in *Pleuronectes* and various other living Bony Fishes, the tail of the early embryo is rounded, and is symmetrically developed at the hinder end of the straight notochord ("leptocardial stage"). Soon the chorda becomes arched upwards, and there appears the first trace of a separation of the tail-fin into two portions, only one of which is destined to remain permanently. The superior of these two divisions, when both have become fully marked out, surrounds the end of the upturned chorda (fig. 254, *a*), and it must be regarded as an embryonic structure, since it finally disappears. The inferior of the two divisions, on the other hand, is placed below the embryonic tail, and is ultimately developed into the permanent tail. At first the permanent caudal fin has the appearance of a distinct lobe, which looks like a second anal fin. In process of growth, however, the embryonic caudal becomes thrown more and more upwards, and the rays of the permanent caudal acquire a fan-like arrangement. At the stage figured below (fig. 254) the tail is truly "heterocercal," and is wonderfully similar in appearance to the tail of many Palæozoic Fishes. Finally, however (fig. 255), the turned-up end of the notochord becomes replaced by the long "urostyle;" the embryonic caudal diminishes in size and disappears; and the permanent caudal increases in size, and is gradually transformed from a ventral into a terminal appendage, the tail-fin thus assuming its permanent "homocercal" form. It would thus appear that the really earliest stage of the tail in the Bony Fishes and Elasmobranchs is the "leptocardial" stage, in which the tail is symmetrical and the notochord straight. This stage is in progress of growth superseded by the "heterocercal" condition, which subsists throughout life in the Elasmobranchs. Finally, the heterocercal tail of the young Bony Fish is in the adult succeeded by the permanent "homocercal" or "diphycercal" tail.

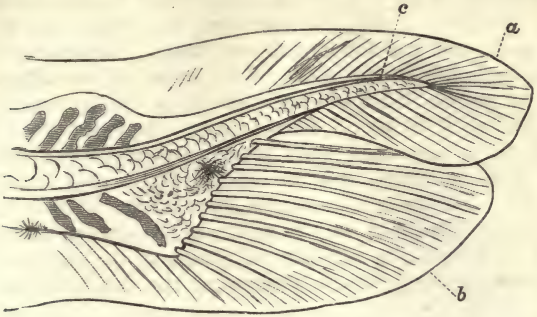

Fig. 254.—Tail of young Flounder (*Pleuronectes*) in its heterocercal stage of development. *a* Embryonic caudal fin; *b* Permanent caudal fin, occupying an inferior position; *c* Bent-up end of the notochord. (After A. Agassiz.)

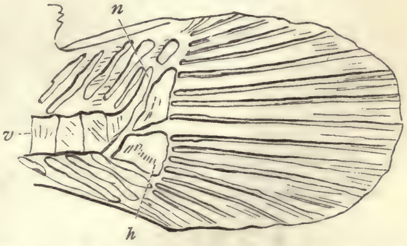

Fig. 255.—Tail of adult Flounder. (After A. Agassiz.) *v* Vertebral column; *n* Turned-up end of the notochord; *h* Hypural bones.

The process of *respiration* in all fishes is essentially aquatic, and is carried on by means of branchial plates or tufts developed upon the posterior visceral arches, which are persistent, and do not disappear at the close of embryonic life, as they do in other Vertebrates. In the Lancelet alone, respiration is effected partly by branchial filaments placed round the commencement of the pharynx, and partly by the pharynx itself, which is greatly enlarged, and has its walls perforated by a series of transverse ciliated fissures. The arrangement and structure of the branchiæ differ a good deal in the different orders of fishes, and these modifications will be noticed subsequently. In the meanwhile it will be sufficient to give a brief description of the branchial apparatus in one of the bony fishes. In such a fish, the branchiæ are connected with the hyoid arch, and are situated in two special chambers, situated one on each side of the neck. The branchiæ are carried upon the outer convex sides of what have been already described as the "branchial arches;" that is to say, upon a series of bony arches (figs. 250 and 256) which are connected with the hyoid arch inferiorly, and are united above with the base of the skull. The internal concave sides of the branchial arches are usually furnished with a series of processes, constituting a kind of fringe, the function of which is to prevent foreign substances finding their way amongst the branchiæ, and thus interfering with the proper action of the respiratory organs. The branchiæ, themselves, usually have the form of a double series of cartilaginous leaflets or laminæ. The branchial laminæ are flat, elongated, and pointed in shape, and they are covered with a highly vascular mucous membrane, in which the branchial capillaries ramify. The blood circulates through the branchial laminæ, and is here subjected to the action of aerated water, whereby it is oxygenated. The water is constantly taken in at the mouth by a movement analogous to swallowing, and it gains admission to the branchial chambers by means of a series of clefts or slits, the "branchial fissures," which are situated on both sides of the pharynx. Having passed over the gills, the deoxygenated water makes its escape

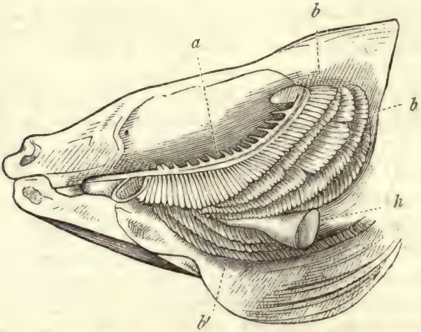

Fig. 256.—Gills and heart of the Perch exposed by the removal of the gill-cover on the left side. *a* First of the four bony arches which carry the gills (*b b*); *b'* The lower edges of the gills on the right side; *h* Heart. (After Van der Hoeven.)

posteriorly by an aperture called the "gill-slit" or "opercular aperture," one of which is situated on each side of the neck. As we have seen before, the gill-slit is closed in front by a chain of flat bones collectively constituting the "gill-cover," or "operculum;" and the gill-covers are finally completed by a variable number of bony spines—the "branchiostegal rays"—which articulate with the hyoid arch, and support a membrane—the "branchiostegal membrane."

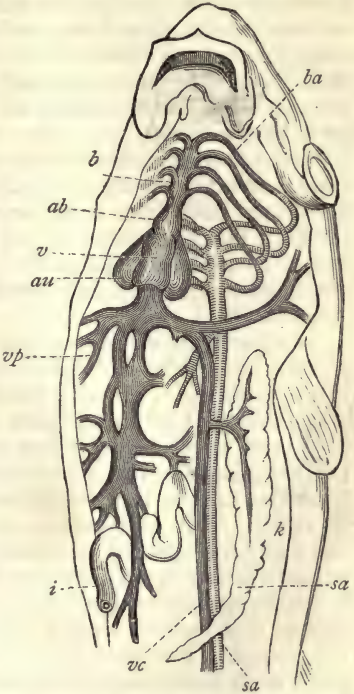

Fig. 257.—Diagram of the circulatory system in a Fish, the vessels containing venous blood being longitudinally shaded, and those containing arterial blood being cross-shaded. *vc* Vena cava; *vp* Vena portæ; *au* Auricle; *v* Ventricle; *ab* Bulbus arteriosus; *b* Branchial artery; *ba* One of the divisions of the branchial artery going to the gills, from which proceeds one of the corresponding branchial veins, by the union of which the subvertebral aorta (*sa*) is formed; *i* Intestine; *k* Kidney.

The *heart* of fishes is, properly speaking, a branchial or respiratory heart. It consists of two cavities, an auricle and a ventricle (fig. 257), and the course of the circulation is as follows: The venous blood derived from the liver and from the body generally is poured by the vena cava into the auricle (*au*), and from this it is propelled into the ventricle (*v*). From the ventricle arises a single aortic arch (the right), and the base of this is usually dilated into a cavity or sinus, called the "bulbus arteriosus" (*ab*). The arterial bulb is sometimes covered with a special coat of striated muscular fibres, and may be provided with several transverse rows of valves. In these cases, the bulbus acts as a kind of continuation of the ventricle, being capable of rhythmical contractions. The blood is driven by the ventricle through the branchial artery (*b*) to the gills, through which it is distributed by means of the branchial vessels, the number of which varies (there are *three* on each side in a few fishes, *four* in most of the Bony Fishes, *five* in the Skates and Sharks, and *six* or *seven* in the Lampreys). The aerated blood which has passed through the gills is not returned to the heart, but is driven from the branchiæ through all parts of the body; the propulsive force necessary for this being derived chiefly from the heart, assisted by the contractions of the voluntary muscles. In some fishes (as in the Eel) the return of the blood to the heart is assisted by a rhythmically contractile dilatation of the caudal vein. The essential peculiarity, then, of the circulation of fishes depends upon this—that the arterialised blood returned from the gills is propelled through the systemic vessels of the body, without being sent back to the heart.

The Lancelet (*Amphioxus*), alone of all fishes, has no special heart, and the circulation is effected by contractile dilatations developed upon several of the blood-vessels. In the Mud-fishes (*Lepidosiren*) the heart consists of *two* auricles and a single ventricle. The blood-corpuscles of fishes are nucleated (fig. 245, *e*), and the blood is red in all except the *Amphioxus*.

As regards the *digestive system* of fishes there is not much of peculiar importance. The mouth is usually furnished with a complicated series of teeth, which, in the Bony Fishes, are not only developed upon the jaws proper, but may be also situated upon other bones which enter into the composition of the buccal cavity (such as the palate, the pterygoids, vomer, branchial arches, the glossohyal bone, &c.) The œsophagus is usually short and capacious, and generally opens into a large and well-marked stomach. The pyloric aperture of the stomach is usually furnished with a valve, and behind it there is usually a number (from one to sixty) of blind appendages, termed the "pyloric cæca." These are believed to represent the pancreas, but there may be a recognisable pancreas either alone or in addition to the pyloric cæca. The intestinal canal is a longer or shorter, more or less convoluted tube, the absorbing surface of which, in certain fishes, is largely increased by a spiral reduplicature of the mucous membrane, which winds like a screw in close turns from the pylorus to the anus. The liver is usually large, soft, and oily, and a gall-bladder is almost universally present; but in the *Amphioxus* the liver is doubtfully represented by a hollow sac-like organ.

The kidneys of fishes are usually of great size, and form two elongated organs, which are situated beneath the spine, and extend along the whole length of the abdominal cavity. The ureters often dilate, and form a species of bladder, the doubtful representative of the allantois.

Whilst the respiration of all fishes is truly aquatic, most of them are, nevertheless, furnished with an organ which has been generally believed to be the homologue of the lungs of the air-breathing Vertebrates. This—the "air" or "swim bladder"—is a sac containing gas, situated beneath the alimentary tube, and often communicating with the gullet by a duct. In the great majority of fishes the functions of the air-bladder are certainly hydrostatic—that is to say, it serves to maintain the necessary accordance between the specific gravity of the fish and that of the surrounding water. In the singular Mud-fishes, (as also in a few Bony Fishes), however, it acts as a respiratory organ, and is therefore not only the homologue, but also the analogue, of the lungs of the higher Vertebrates. In most fishes the air-bladder is an elongated sac with a single cavity, but in many cases it is variously subdivided by septa, or it may give off more or less complicated cæca (fig. 258). In the Mud-fishes the air-bladder is composed of two sacs, completely separate from one another, and divided into a number of cellular compartments. The duct (*ductus pneumaticus*) leading in many fishes from the air-bladder, and opening into the œsophagus, is the homologue of the windpipe (*trachea*). The air contained in the swim-bladder is composed mainly of nitrogen in most fresh-water fishes, but in the sea-fishes it is mainly made up of oxygen. The fishes which live habitually at the bottom of the sea, such as the Flat-fishes, possess no swim-bladder, and it is much reduced in size in those which live principally at the surface.

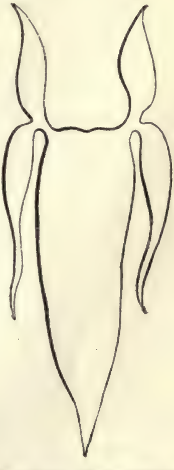

Fig. 258.—Swim-bladder of *Corvina trispinosa*, showing appended cæca.

The *nervous system* of fishes is of an inferior type of organisation, the brain being of small size, and consisting mainly of ganglia devoted to the special senses. As regards the special senses, there is one peculiarity which deserves particular notice, and this is the conformation of the nasal sacs. The cavity of the nose is usually double, and is lined by an olfactory membrane, folded so as to form numerous plicæ. Anteriorly, the water is admitted into the nasal sacs by a single or double nostril, usually by two apertures; but posteriorly the nasal sacs are closed, and do not communicate with the pharynx by any aperture. The only exceptions to this statement are to be found in the Myxinoids and in the Mud-fishes.

The essential portion of the organ of hearing (*labyrinth*) is present in almost all fishes, but in none is there any direct communication between the ear and the external medium. In some cases, however, there is a communication between the ear and the swim-bladder, thus foreshadowing the Eustachian tube in man.

As regards their *reproductive system*, fishes are, for the most part, truly *oviparous*, the ovaries being familiarly known as the "roe." The testes of the male are commonly called the "soft roe," or "milt." The products of the reproductive organs are often set free into the peritoneal cavity, ultimately finding their way to the external medium by means of an abdominal pore (or pores); or they are directly conveyed to the exterior by the proper ducts of the reproductive organs.

DIVISIONS OF FISHES.

CHAPTER LII.

PHARYNGOBRANCHII AND MARSIPOBRANCHII.

THE class *Pisces* has been very variously subdivided by different writers; but the classification here adopted is the one proposed by Professor Huxley, who divides the class into the following six orders, in the subdivisions of which Professor Owen has been followed: *

ORDER I. PHARYNGOBRANCHII (= *Cirrostomi*, Owen; and *Leptocardia*, Müller).—This order includes but a single fish, the anomalous *Amphioxus lanceolatus*, or Lancelet (fig. 259), the organisation of which differs in almost all important points from that of all the other members of the class. The characters of *Amphioxus*, in fact, are so aberrant, that Hæckel proposes to divide the sub-kingdom *Vertebrata* into two primary sections—the one (*Leptocardia*) comprising the Lancelet alone, whilst the other (*Pachycardia*) includes all other Vertebrates. The order is defined by the following characters, which, as will be seen, are mostly negative:—*No skull is present, nor lower jaw (mandible), nor limbs. The notochord is persistent; and there are no vertebral centra nor arches. No distinct brain nor auditory organs are present. In place of a distinct heart, pulsating dilatations are developed upon several of the great blood-vessels. The blood is pale. The mouth is in the form of a longitudinal fissure, surrounded by filaments or cirri. The walls of the pharynx are perforated by numerous clefts or fissures, the sides of which are ciliated, the whole exercising a respiratory function.*

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* Cuvier divided the class *Pisces* into the great orders of the *Chondropterygii* (or Cartilaginous Fishes), the *Acanthopterygii* (or Fishes with spinous rays in the paired fins), and *Malacopterygii* (or Fishes with soft rays in the paired fins). Agassiz divides Fishes, from the character of the scales, into the four orders, *Cycloidei*, *Ctenoidei*, *Ganoidei*, and *Placoidei*. Müller divides the Fishes into the five orders *Leptocardia*, (Lancelet), *Cyclostomata* (Lampreys and Hag-fishes), *Teleostei*, (Bony Fishes), *Ganoidei*, (Ganoid Fishes), and *Selachia* (Sharks and Rays).

The Lancelet is a singular little fish, from one to two inches in length, which is found burrowing in sandbanks, in various seas, but especially in the Mediterranean. The body (fig. 259) is semi-transparent, destitute of an exoskeleton, and lanceolate in shape, and is provided with a narrow membranous border, of the nature of a median fin, which runs along the whole of the dorsal and part of the ventral surface, and expands at the tail to form a lancet-shaped caudal-fin. No true paired fins, representing the anterior and posterior limbs, are present. The mouth is a longitudinal fissure, situated at the front of the head, and destitute of jaws. It is surrounded by a cartilaginous ring, composed of many pieces, which give off prolongations, so as to form a number of ciliated cartilaginous filaments or "cirri" on each side of the mouth. (Hence the name of *Cirrostomi*, proposed by Professor Owen for the order.) The throat is provided on each side with vascular lamellæ, which are believed by Owen to perform the function of free branchial filaments. The mouth leads into a dilated chamber (fig. 259, *b*), which is believed to represent the pharynx, and is termed the "pharyngeal" or "branchial sac." It is an elongated chamber, the walls of which are strengthened by numerous cartilaginous filaments, between which is a series of transverse slits or clefts, the whole covered by a richly-ciliated mucous membrane. This branchial dilatation has given rise to the name *Branchiostoma*, often applied to the Lancelet. Posteriorly the branchial sac opens into an alimentary canal, to which is appended a long and capacious sac or cæcum (*h*), which is believed to represent the liver. The intestinal tube terminates posteriorly by a distinct anus (*a*), which is situated at the root of the tail a little to the left of the median line; and the intestinal mucous membrane is ciliated. Respiration is effected by the admission of water taken in by the mouth into the branchial sac, having previously passed over the free

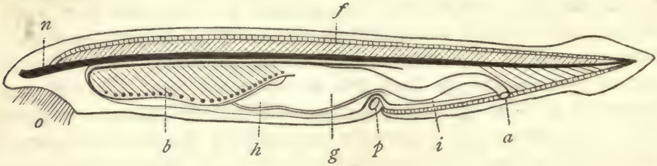

Fig. 259.—The Lancelet (*Amphioxus lanceolatus*), enlarged to twice its natural size. *o* Mouth; *b* Pharyngeal sac; *g* Stomach; *h* Diverticulum representing the liver; *i* Intestine; *a* Anus: *n* Notochord; *f* Rudiments of fin-rays; *p* Abdominal pore.

branchial filaments before mentioned. The water passes through the slits in the branchial sac, and thus gains access to the abdominal cavity, from which it escapes by means of an aperture with contractile margins situated a little in front of the anus, and called the "abdominal pore" (*p*). There is no distinct heart, and the circulation is entirely effected by means of rhythmically contractile dilatations which are developed upon several of the great blood-vessels. In other words, the heart retains its primitively tubular condition, and special contractile dilatations are developed upon other vessels (those carrying the blood to the pharynx). The blood itself is colourless. No kidneys have as yet been certainly identified, and there is no lymphatic system. There is no skeleton properly so called. In place of the vertebral column, and constituting the whole endoskeleton, is the semi-gelatinous cellular notochord (*n*), enclosed in a fibrous sheath, and giving off fibrous arches above and below. The notochord is, further, peculiar in this, that it is prolonged quite to the anterior end of the body, whereas in all other Vertebrates it stops short at the pituitary fossa. There is no cranium, and the spinal cord does not expand anteriorly to form a distinct cerebral mass. The brain, however, may be said to be represented, since the anterior portion of the nervous axis gives off nerves to a pair of rudimentary eyes, and another branch to a ciliated pit, believed to represent an olfactory organ. The generative organs (ovaria and testes) are not furnished with any efferent ducts (oviduct or vas deferens). The generative products, therefore, are shed into the abdominal cavity, and gain the external medium by the "abdominal pore."

ORDER II. MARSIPOBRANCHII (= *Cyclostomi*, Owen; and *Cyclostomata*, Müller).—This order includes the Lampreys (*Petromyzonidæ*) and the Hag-fishes (*Myxinidæ*), and is defined by the following characters:—*The body is cylindrical, worm-like, and destitute of limbs. The skull is cartilaginous, without cranial bones, and having no lower jaw* (*mandible*). *The notochord is persistent, and there are either no vertebral centra, or but the most rudimentary traces of them. The heart consists of one auricle and one ventricle, but the branchial artery is not furnished with a bulbus arteriosus. The gills are sac-like, and are not ciliated.*

The type of piscine organisation displayed in the *Marsipobranchii* is of a very low grade, as indicated chiefly by the persistent notochord without vertebral centra, the absence of any traces of limbs, the absence of a mandible, and the structure of the gills.

Both the Lampreys (fig. 260, B) and the Hag-fishes (fig. 260, A) are vermiform, eel-like fishes, which agree in possessing no paired fins to represent the limbs, but in having a median fin running round the hinder extremity of the body. The skeleton remains throughout life in a cartilaginous condition, the chorda dorsalis is persistent, and the only traces of bodies of vertebræ are found in hardly perceptible rings of osseous matter developed in the sheath of the notochord. The neural arches of the vertebræ, enclosing the spinal cord, are only represented by cartilaginous prolongations. There is a partially cartilaginous cranium, which is not, however, movable on the spinal column. The mouth in the Hag-fish (*Myxine*) is of a very remarkable character, and enables it to lead a very peculiar mode of life. It is usually found, namely, embedded in the interior of some other large fish, into which it has succeeded in penetrating by means of its singular dental apparatus. The mouth (fig. 260, A) is sucker-like, destitute of jaws, but provided with tactile filaments or cirri. In the centre of the palate is fixed a single, large, recurved fang, which is firmly attached to the under surface of the cranium. The sides of this fang are strongly serrated, and it is by means of this that the Hag-fish bores its way into its victim, having previously attached itself by its sucker-like mouth, assisted by the action

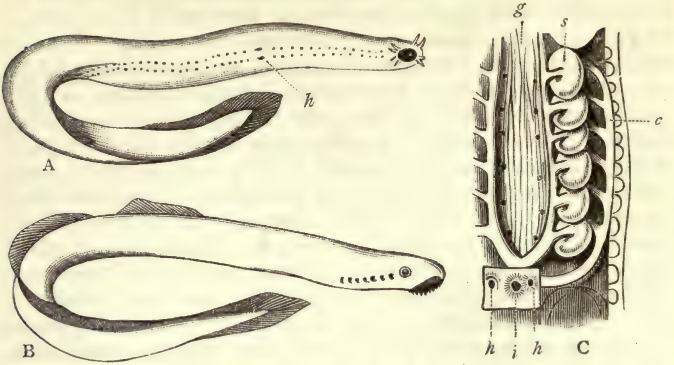

Fig. 260.—Morphology of Marsipobranchii. A, *Myxine glutinosa*, showing the sucker-like mouth, and the two ventral openings (*h*) by which the water escapes from the gills. B, The River Lamprey or Lampern (*Petromyzon fluviatilis*), showing the seven branchial apertures on the side of the neck. C, Branchial organs of *Myxine*; *g* The gullet laid open, showing the openings (six on each side) by which the water enters the branchial sacs (*s*); *c* Canal carrying the water away from the gills, to be discharged by the two ventrally-placed branchial apertures (*h*, *h*); *i* Aperture by which the water is admitted to the gullet and thence to the gills.

of the piston-like toothed tongue. In the Lampreys the mouth has also the form of a circular cup or sucker, and is also destitute of jaws; but in addition to the palatine fang of the *Myxine*, the margins of the lips bear a number of horny processes, which are not really true teeth, but are hard structures developed in the labial mucous membrane. The tongue, also, is armed with serrated teeth, and acts as a kind of piston; so that the Lampreys are in this manner enabled to attach themselves firmly to solid objects. Sometimes the oral cavity is strengthened by a basket-shaped cartilaginous apparatus, and sometimes a similar apparatus supports the gill-sacs. The alimentary canal is simple and straight, the liver not sac-like, but of its ordinary form, and the kidneys distinct and well developed.

The *Marsipobranchii* are peculiar amongst Vertebrate animals in possessing only one median nasal sac, opening on the exterior of the head by a single unpaired nostril. The Hag-fishes further differ from all the members of the class, except the Mud-fishes (*Dipnoi*) in the fact that the nasal cavity communicates behind with the pharynx. In the Lampreys, on the other hand, the nasal sac is closed posteriorly.

Another very remarkable point in the Hag-fishes and Lampreys is to be found in the structure of the gills, from which the name of the order is derived. The gills, namely, are in the form of fixed pouches, instead of being free vascular structures contained in a common chamber, opening externally by a gill-slit, as in the typical Bony Fishes. In the Hag-fishes there are six of these branchial sacs on each side of the œsophagus (fig. 260, C). The water is admitted to the gullet (*g*) by a special aperture situated on the ventral surface, whence it passes into the branchial pouches by six apertures on each side. Having passed over the complicated and highly vascular interior of the branchial sacs, the water escapes by a corresponding series of tubes opening into a common canal (*c*) on each side, and these canals finally discharge the effete water by two apertures situated on the ventral surface behind the head (*h*, *h*). In the Lampreys the gills have the same fixed and pouch-like arrangement, but there are some marked differences from the above. The water is admitted from the gullet to seven branchial pouches on each side, but the mode of admission is by means of two special canals which lie beneath the œsophagus on each side, communicating each by its own aperture with the mouth in front, terminating blindly behind, and sending off a branch to each pouch. The effete water, also, escapes by a special tube to each sac, so that there are seven branchial apertures in the form of slits or holes on the side of the neck (fig. 260, B). The reproductive organs are ductless, and the generative elements are shed into the abdomen, whence they escape by an abdominal pore.

The Lampreys are, some of them, inhabitants of rivers; but the great Sea-lamprey (*Petromyzon marinus*) only quits the salt water in order to spawn. The mouth in the *Petromyzonidæ* is a circular cartilaginous ring, formed by the amalgamation of the palatine and mandibular arches, and carrying numerous teeth and small tubercles. The tongue is armed with a double series of small teeth, and acts like a piston, enabling the animal to attach itself to stones and rocks. There is no air-bladder. The body is cylindrical, compressed towards the tail, and destitute of scales. The skeleton consists of a series of cartilaginous rings without ribs. The young *Petromyzon* undergoes a metamorphosis, being so unlike the parent that a new genus (*Ammocœtes*) was originally founded for its reception.

In the *Myxinidæ* the mouth is circular and membranous, with eight cirri. The palate carries a single fang, and the tongue is armed with a double row of small teeth on each side. There may be seven branchial apertures on each side (*Heptatrema*), or the branchial pouches open into a common tube on each side, and each of these terminates in a distinct aperture situated under the heart on the lower surface of the body (*Myxine* or *Gastrobranchus*). The Hags pour out so much mucus through the lateral line that they can surround themselves with jelly; hence the name of the common species (*Myxine glutinosa*). The Glutinous Hag is a native of the North and British seas, and is chiefly found in the interior of the Cod and Haddock (often five or six individuals in one fish).

CHAPTER LIII.

TELEOSTEI.

ORDER III. TELEOSTEI.—This order includes the great majority of fishes in which there is a well-ossified endoskeleton, and it corresponds very nearly with Cuvier's division of the "osseous" fishes. The *Teleostei* are defined as follows:—*The skeleton is usually well ossified; the cranium is provided with cranial bones; and a mandible is present; whilst the vertebral column almost always consists of more or less completely ossified vertebræ. The pectoral arch has a clavicle; and the two pairs of limbs, when present, are in the form of fins supported by rays. The gills are free, pectinated or tufted in shape; a bony gill-cover and branchiostegal rays being always developed. The branchial artery has its base developed into a bulbus arteriosus; but this is never rhythmically contractile, and is separated from the ventricle by no more than a single row of valves.*

The order *Teleostei* comprises almost all the common fishes; and it will be unnecessary to dilate upon their structure, as they were taken as the types of the class in giving a general description of the Fishes. It may be as well, however, to recapitulate very briefly some of the leading characters of the order.

I. The *skeleton*, instead of remaining throughout life more or less completely cartilaginous, is now always more or less thoroughly ossified. The notochord is not persistent, and the vertebral column, though sometimes cartilaginous, consists of a number of vertebræ. The bodies of the vertebræ are what is called "amphicœlous"—that is to say, they are concave at both ends. It follows from this, that between each pair of vertebræ there is formed a doubly-conical cavity, and this is filled with the cartilaginous or semi-gelatinous remains of the notochord. By this means an extraordinary amount of flexibility is given to the entire vertebral column. In no fish except the Bony Pike (which belongs to the order *Ganoidei*) is the ossification of the vertebral centra carried further than this. The skull is of an extremely complicated nature, being composed of a number of distinct cranial bones; and a mandible or lower jaw is invariably present.

II. The anterior and posterior pairs of limbs are usually, but not always, present, and when developed they are always in the form of fins. The fins may be supported by "spinous" or "soft" rays, of which the former are simple undivided spines of bone, whilst the latter are divided transversely into a number of short transverse pieces, and also are broken up into a number of longitudinal rays proceeding from a common root. (The fishes with soft rays in their paired fins are termed "*Malacopterygii*"—those with spinous rays, "*Acanthopterygii.*")

III. Besides the paired fins, representing the limbs, there is a variable number of unpaired or azygous integumentary expansions, which are known as the "median fins." When fully developed (fig. 261), they consist of one, two, or three fins on the back—the "dorsal" fins; one or two on the ventral surface—the "anal" fins; and one clothing the posterior extremity of the body—the "caudal" fin. The caudal fin (fig. 253, A) is set vertically, and not horizontally, as in the Whales and Dolphins; and in all the bony fishes its form is "homocercal"—that is, it consists of two equal lobes, and the vertebral column is not prolonged into the superior lobe.* In all the median fins the fin-rays are supported upon a series of dagger-shaped bones, which are plunged in the flesh of the middle line of the body, and are attached to the spinous processes of the vertebræ. These are the so-called "interspinous" bones.

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* Though to all appearance symmetrical, the tail of the bony fishes is in reality generally unsymmetrical. The appearance of symmetry is due to the bony spinal column terminating in the centre of a wedge-shaped

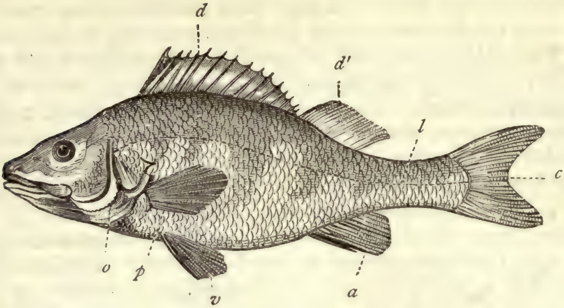

Fig. 261.—The common Perch (*Perca fluviatilis*). *o* Gill-cover, with the gill-slit behind it; *p* One of the pectoral fins, the left; *v* The left ventral fin; *d* The first dorsal fin; *d'* The second dorsal fin; *c* The caudal fin or tail; *a* The anal fin; *l* Lateral line.

IV. The *heart* consists of two chambers, an auricle and a ventricle, and the branchial artery is furnished with a bulbus arteriosus. The arterial bulb, however, is not furnished with a special coat of striated muscular fibres, is not rhythmically contractile, and is separated from the ventricle by no more than a single row of valves.

V. The *respiratory organs* consist of free, pectinated, or tufted branchiæ, situated in two branchial chambers, each of which communicates internally with the pharynx by a series of clefts, and opens externally on the side of the neck by a single aperture (or "gill-slit"), which is protected in front by a bony gill-cover (fig. 261) and is also closed by a "branchiostegal membrane," supported upon "branchiostegal rays." The branchiæ are attached to a series of bony branchial arches (generally five on each side, but only the anterior four bearing gills), which are connected inferiorly with the hyoid bone, and superiorly with the skull; and the water required in respiration is taken in at the mouth by a process analogous to swallowing.

"hypural bone," to the free edges of which the caudal fin-rays are symmetrically attached. The actual termination of the notochord is bent up, and is never ossified; but its sheath usually becomes calcified, forming a spine ("urostyle") which coalesces with the dorsal edge of the hypural bone, the latter being formed by the anchylosis of ossicles developed from the ventral face of the notochordal sheath.

VI. The nasal sacs never communicate posteriorly with the cavity of the pharynx.

VII. The exoskeleton usually has the form of overlapping horny scales of the cycloid or ctenoid character; but it is sometimes absent, sometimes composed of scattered plates of true bone, sometimes ganoid, and sometimes formed of shagreen-like bony spines.

VIII. The stomach is capacious; pyloric cæca are present; the intestine has no spiral valve; and the rectum usually opens separate from and in front of the urinary and genital apertures. The air-bladder may or may not be present, and may or may not communicate with the gullet. The kidneys are well developed. The reproductive organs may be solid, and may liberate their contents by rupture into the abdominal cavity; but they are usually hollow organs, with ducts which open beside or behind the urinary aperture.

The subdivisions of the osseous fishes are so numerous, and they contain so many families, that it will be sufficient to run over the more important sub-orders, and to mention the more familiar examples of each.

SUB-ORDER A. MALACOPTERI, Owen (= *Physostomata*, Müller).—This sub-order is defined by usually possessing a complete set of fins, supported by rays, all of which are "*soft*" or many-jointed, with the occasional exception of the first rays in the dorsal and pectoral fins. A swim-bladder is always present, and always communicates with the œsophagus by means of a duct, which is the homologue of the windpipe. The skin is rarely naked, and is mostly furnished with cycloid scales; but in some cases ganoid plates are present.

This sub-order is one of great importance, as comprising many well-known and useful fishes. It is divided into two groups, according as ventral fins are present or not. In the first group—*Apoda*—there are no ventral fins; and the most familiar examples are the common Eels of our own country. The Eels (*Murænidæ*) have an elongated, almost cylindrical body, with the scales deeply sunk in the skin, and scarcely apparent. A swim-bladder is present, and the operculum is small and mostly enveloped in the skin. More remarkable, however, than the ordinary Eels is the *Gymnotus electricus*, or great Electric Eel (fig. 262), which inhabits the marshy waters of those wonderful South American plains, the so-called "Llanos," and which shares with various fishes of diverse affinities (the Torpedo, the *Malapterurus electricus*, &c.) the power of generating electricity by means of special organs.

The second group of the *Malacopteri* is that of the *Abdominalia*, in which there are ventral fins, and these are abdominal in position. Space will not permit of more here than merely mentioning that in this section are contained amongst others the well-known and important groups of the *Clupeidæ* (Herring tribe), the Pikes (*Esocidæ*), the Carps, Barbels, Roach, Chub, Minnow, &c. (*Cyprinidæ*), and the *Salmonidæ*, comprising the various species of Salmon and Trout. Also belonging to this group are the Sheat-fishes (*Siluridæ*), which are chiefly noticeable because they are amongst the small number of living fishes possessed of structures of the same nature as the fossil spines known as "ichthyodorulites." The structure in question consists of the first ray of the pectoral fins, which is largely developed, and constitutes a formidable spine, which the animal can erect and depress at pleasure. Unlike the old "ichthyodorulites," however, the spines of the *Siluridæ* have their bases modified for articulation with another bone, and they are not simply hollow and implanted in the flesh. The "Siluroids" are also remarkable for their resemblance to certain of the extinct Ganoid fishes (*e.g.*, *Pterichthys*, *Coccosteus*, &c.), caused by the fact that the head is protected with an exoskeleton of dermal bones. The largest European species is the *Silurus glanis* of the Swiss lakes, and of various European rivers. Another remarkable member of this family is the *Malapterurus* of the Nile and West Coast of Africa, which is endowed with electrical powers.

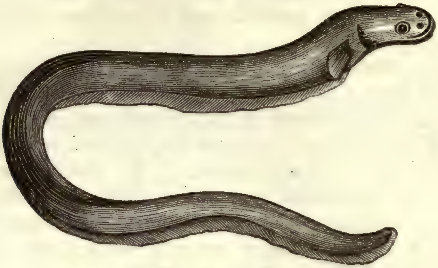

Fig. 262 —Electric Eel (*Gymnotus electricus*).

SUB-ORDER B. ANACANTHINI.—This sub-order is distinguished by the fact that the fins are entirely supported by "soft" rays, and never possess "spiny" rays; whilst the ventral fins are either wanting, or, if present, are placed under the throat, beneath or in advance of the pectorals, and supported by the pectoral arch. The swim-bladder may be wanting, but when present it does not communicate with the œsophagus by a duct.

As in the preceding order, the *Anacanthini* are divided into two groups, distinguished by the presence or absence of the ventral fins. In the first of these groups (*Apoda*) are only a few fishes, of which one of the most familiar examples is the little Sand-eel (*Ammodytes lancea*), which occurs on all our coasts. In the second group (*Sub-brachiata*), in which ventral fins exist, are the two important families of the *Gadidæ* and *Pleuronectidæ*. The *Gadidæ* or Cod family, comprising the Haddock, Whiting, Ling, and Cod itself, is of great value to man, most of its members being largely consumed as food. In the *Pleuronectidæ* or Flat-fishes are comprised the Sole, Plaice, Turbot, Halibut, Brill, and others, in all of which there is a very curious modification in the form of the body. The body, namely, in all the Flat-fishes (fig. 263) is very much compressed from side to side, and is bordered by long dorsal and anal fins. When young, the body is symmetrical, the eyes are bilaterally situated, and the animal swims in a vertical position. Soon, the habit of lying on one side (sometimes the right, but more commonly the left, side) is commenced, and then the eye upon the lower side is gradually translated to the upper side of the head; this translation being effected by an actual movement of the lower eye, or by its passing through the at that time soft tissues of the head, a partial twisting of the cranial bones assisting to bring about the final result. When adult, both eyes are situated upon one side of the head (fig. 263), and the fish now keeps this side uppermost, and is dark-coloured on this aspect; whilst the opposite side, on which it rests, is white. From this habit of the Flat-fishes of resting upon one flat surface, the sides are often looked upon as the dorsal and ventral surfaces of the body. This, however, is erroneous, as they are shown by the position of the paired fins to be truly the *lateral* surfaces of the body. The mouth has its two sides unequal, the pectorals are rarely of the same size, the ventrals look like a continuation of the anal fin, and the branchiostegal rays are six in number.

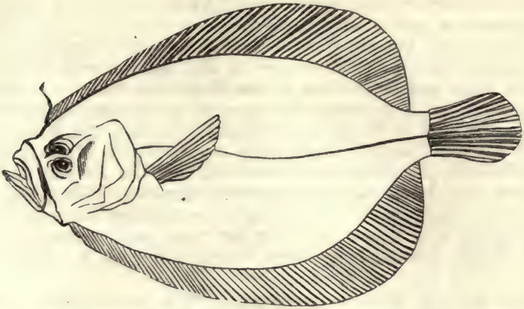

Fig. 263.—Pleuronectidæ. *Rhombus punctatus*. Natural size (after Gosse).

Sub-order C. Acanthopteri.—This sub-order is characterised by the fact that one or more of the first rays in the fins are in the form of true, unjointed, inflexible, "spiny" rays. The exoskeleton consists, as a rule, of ctenoid scales. The ventral fins are generally beneath or in advance of the pectorals, and the duct of the swim-bladder is invariably obliterated.

This sub-order comprises two families :—

a. The *Pharyngognathi*, in which the inferior pharyngeal bones are anchylosed so as to form a single bone, which is usually armed with teeth. The family is not of much importance, the only familiar fishes belonging to it being the "Wrasses" (*Cyclolabridæ*).

b. The *Acanthopteri veri*, characterised by having always spiny rays in the first dorsal fin, and usually in the first rays of the other fins, whilst the inferior pharyngeal bones are never anchylosed into a single mass. This family includes many subordinate groups, and may be regarded as, on the whole, the most typical division of the Teleostean fishes. It will not be necessary, however, to do more than mention as amongst the more important fishes contained in it, the Perch family (*Percidæ*), the Mullets (*Mugilidæ*), the Mackerel family (*Scomberidæ*), the Gurnards (*Sclerogenidæ*), the Gobies (*Gobiidæ*), the Blennies (*Blenniidæ*), and the Anglers (*Lophiidæ*). The *Percidæ* form by far the most important member of this group, and are distinguished by having ctenoid scales, the operculum and præ-operculum variously armed with spines, teeth on the vomer and palate as well as on the jaws, and the branchiostegal rays from five to seven in number.

SUB-ORDER D. PLECTOGNATHI.—This sub-order is characterised by the fact that the maxillary and præmaxillary bones are immovably connected on each side of the jaw. The endoskeleton is only partially ossified, and the vertebral column often remains permanently cartilaginous. The exoskeleton is in the form of ganoid plates, scales, or spines. The ventral fins are generally wanting, and the air-bladder is destitute of a duct.

The most remarkable fishes of this section are the Trunk-fishes (*Ostracionidæ*, in which the body is entirely enclosed, with the exception of the tail, in an immovable case, composed of large ganoid plates, firmly united to one another at their edges.

Besides the Trunk-fishes, this section also includes the File-fishes (*Balistidæ*) and the Globe-fishes (*Gymnodontidæ*).

SUB-ORDER E. LOPHOBRANCHII.—This is a small and unimportant group, mainly characterised by the peculiar structure of the gills, which are arranged in little tufts upon the branchial arches, instead of the comb-like plates of the typical Bony Fishes. The endoskeleton is only partially converted into bone, and the exoskeleton, by way of compensation, consists of ganoid plates. The swim-bladder is destitute of an air-duct.

The singular Sea-horses (*Hippocampidæ*), now kept in most of our large aquaria, belong to this sub-order, but the only point about them which requires notice is the curious fact that the males in this family are provided with a sort of marsupial pouch, into which the eggs are placed by the female, and to which the young, when hatched, can retire if threatened by any danger. This singular cavity is only found in the males, and is situated at the base of the tail. More familiar than the Sea-horses are the Pipe-fishes (*Syngnathidæ*), of which one species occurs commonly on our shores.

CHAPTER LIV.

GANOIDEI.

Order IV. Ganoidei.—The fourth order of fishes is the large and important one of the *Ganoid* fishes, represented, it is true, by few living forms, but having an enormous development in past geological epochs. For this reason the study of the Ganoid fishes is one which claims considerable attention.

At the present day, the order *Ganoidei* comprises only seven genera—viz., *Lepidosteus*, *Polypterus*, *Calamoichthys*, *Amia*, *Acipenser*, *Scaphirhynchus*, and *Spatularia*—all of which are found only in the northern hemisphere, and are wholly or partially confined to fresh water.

The order *Ganoidei* may be defined by the following characters: *The endoskeleton is only partially ossified, the vertebral column mostly remaining cartilaginous throughout life, especially amongst the extinct forms of the Palæozoic period, in which the notochord is often persistent. The skull is furnished with distinct cranial bones, and the lower jaw is present. The exoskeleton is in the form of ganoid scales, plates, or spines. There are usually two pairs of limbs, in the form of fins, each supported by fin-rays. The first rays of the fins are mostly in the form of strong spines. The pectoral arch has a clavicle, and the posterior limbs (ventral fins) are placed close to the anus. The caudal fin is mostly unsymmetrical or "heterocercal." The swim-bladder is always present, is often cellular, and is provided with an air-duct. The intestine is often furnished with a spiral valve. The gills and opercular apparatus are essentially the same as in the Bony Fishes. The heart has one auricle and a ventricle, and the base of the branchial artery is dilated into a bulbus arteriosus, which is rhythmically contractile, is furnished with a distinct coat of striated muscular fibres, and is provided with several transverse rows of valves.*

Of these characters, the ones which it is most important to remember are the following:—

I. The *endoskeleton* is rarely thoroughly ossified, but varies a good deal as to the extent to which ossification is carried. In some forms, including most of the older members of the order, the chorda dorsalis is persistent, no vertebral centra are developed, and the skull is cartilaginous, and is protected by ganoid plates. Even in these forms, however, the peripheral elements of the vertebræ may be ossified. In others, the bodies of the vertebræ are marked out by osseous or semi-cartilaginous rings, enclosing the primitive matter of the notochord. In others, the vertebræ are like those of the Bony Fishes; that is to say, deeply biconcave or "amphicœlous." In one Ganoid, however—the Bony Pike (*Lepidosteus*)—the vertebral column consists of a series of "opisthocœlous" vertebræ; that is to say, vertebræ which are convex in front and concave behind. This is the highest point of development reached in the spinal column of any fish, and its structure is more Reptilian than Piscine. In *Polypterus* and *Amia* the vertebræ are ossified and amphicœlous. The remaining existing genera have a persistent notochord.

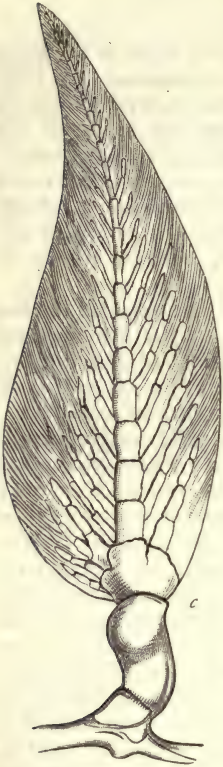

Fig. 264.—Skeleton of the pectoral fin of *Ceratodus*, showing the median axis and divergent branches on each side. *c* Carpal cartilage. (After Günther.)

II. The *exoskeleton* consists in most Ganoid fishes of scales, plates, or spines, which are said to possess *ganoid* characters. The peculiarities of these scales are that they are composed of two distinct layers—an inferior layer of bone and a superficial covering of a kind of enamel, somewhat similar to the enamel of the teeth, called "ganoine." In form the ganoid scales most typically exhibit themselves as rhomboidal plates, placed edge to edge, without overlapping, in oblique rows, the plates of each row being often articulated to those of the next by distinct processes (fig. 247, *e*). In some cases, however, the scales are circular, and overlap one another, as in the ordinary Bony Fishes. In *Acipenser* (fig. 253, B) and *Scaphirhynchus* there are detached dermal plates of true bone; whilst *Spatularia* has the skin naked.

III. As to the *fins*, both pectorals and ventrals are usually present, and the ventrals are always placed far back in the neighbourhood of the anus, and are never situated in the immediate vicinity of the pectorals. In some living and many extinct forms the fin-rays of the paired fins are arranged so as to form a fringe round a central lobe (fig. 265). This structure characterises a large and important division of Ganoid fishes, called by Professor Huxley, for this reason, "Fringe-finned" Ganoids or *Crossopterygidæ*. The same form of fin is seen in *Ceratodus* among the *Dipnoi*, in which the limb (fig. 264) consists of a median cartilaginous axis, formed by a succession of joints, which, in turn, support on each side a lateral series of jointed branches, these finally bearing the fin-rays. The form of the caudal fin varies, the Ganoids being in this respect intermediate between the Bony Fishes, in which the tail is "homocercal," and the Sharks and Rays, in which there is a "heterocercal" caudal fin. In the majority of Ganoids, then, the tail is unsymmetrical or "heterocercal," but it is sometimes equi-lobed or "homocercal."

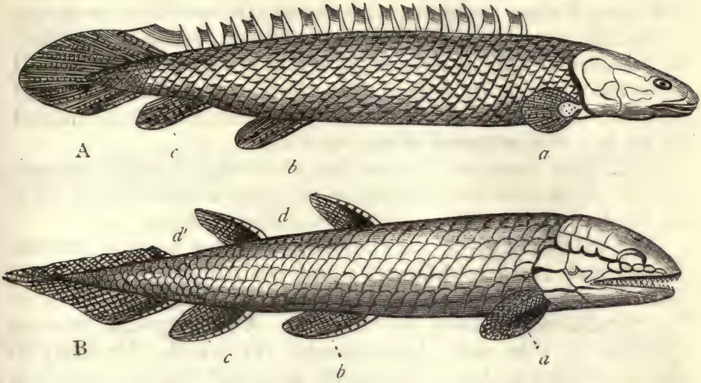

Fig. 265.—Ganoid Fishes. A, *Polypterus*; B, *Osteolepis* (extinct). *a* One of the pectoral fins, showing the fin-rays arranged round a central lobe; *b* One of the ventral fins; *c* Anal fin; *d* Dorsal fin; *d'* Second dorsal fin.

IV. As to the structure of the *respiratory organs*, the Ganoid Fishes agree essentially with the Bony Fishes. They all possess *free* pectinated gills attached to branchial arches, and enclosed in a branchial chamber, which is protected by an operculum, and is closed by a branchiostegal membrane, usually supported by branchiostegal rays. Besides the ordinary branchiæ there is frequently an additional gill, called the "opercular branchia," attached to the interior of each operculum, and below this a false gill or "pseudo-branchia," which receives arterialised blood only. *Acipenser* and *Polypterus* have "spiracles" placed on the top of the head and communicating with the mouth.

V. There is always a swim-bladder, which is often divided by partitions into several cells, and is always connected with the gullet by an air-duct, as in the Malacopterous division of the Teleostean fishes. In *Polypterus* the air-bladder is double and sacculated.

VI. As to the structure of the *heart*, the Ganoids differ from the Bony Fishes, and agree with the Sharks and Rays in having a rhythmically contractile bulbus arteriosus, which is furnished with a special coat of striated muscular fibres, and is separated from the ventricle by several rows of valves. This is a decided advance in structure, as in this way the arterial bulb is enabled to act as a continuation of the ventricle.

VII. The intestine is often furnished with a spiral reduplication of its mucous membrane, forming a spiral valve, such as we shall afterwards see in the Sharks and Rays.

The *classification* of the Ganoid fishes has hitherto proved a matter of extreme difficulty; and probably no arrangement that has been as yet proposed can be regarded as being, in all its details, more than provisional. A convenient primary division is that into *Lepidoganoids*, in which the body is furnished with scales of moderate size, and the endoskeleton is generally more or less perfectly ossified, and *Placoganoids*, in which the skeleton is imperfectly ossified, and the head and more or less of the body are protected by large ganoid plates, which in many cases are united together by sutures. Accepting this division, the order *Ganoidei* may be divided into the following sub-orders:—

SECTION 1. LEPIDOGANOIDEI.

Sub-order A. *Amiadæ.*
" B. *Lepidosteidæ.*
" C. *Crossopterygidæ.*
" D. *Acanthodidæ.* (Extinct.)

SECTION 2. PLACOGANOIDEI.

Sub-order E. *Ostracostei.* (Extinct.)
" F. *Chondrosteidæ.*

The best known living fishes belonging to the Lepidoganoids are the Bony Pike and the *Polypterus*. The Bony Pike (*Lepidosteus*, fig. 266, A) inhabits the rivers and lakes of North America, and atttains a length of several feet. The body is entirely clothed with an armour of ganoid scales, arranged in obliquely transverse rows. The vertebral column is exceedingly well ossified, and is reptilian in its characters, the bodies of the vertebræ being "opisthocœlous." The jaws form a long narrow snout, armed with a double series of teeth; and the tail is heterocercal.

The *Polypteri*, of which several species are known, inhabit the Nile, Senegal, and other African rivers, and are remarkable for the peculiar structure of the dorsal fin (fig. 265, A), which is broken up into a number of separate portions, each composed of a single spine in front, with a soft fin attached to it behind. They belong to the Crossopterygious Ganoids, in which the pectoral fins always, and the ventral fins often, consist of a central lobe or stem, which is covered with scales, and to the sides of which the fin-rays are attached. Two species of *Polypterus* have recently been shown to possess *external* branchiæ when young, losing them when fully grown. *Calamoichthys*, also from the rivers of Africa, resembles *Polypterus* in most respects, but the body is serpentiform, and there are no ventral fins. Another group of Lepidoganoids is formed by the Trout-like *Amiæ* of the fresh waters of the United States, in which the scales are rounded and overlap one another, the tail is slightly heterocercal, and the vertebral column is ossified. The air-bladder in *Amia* is subdivided, and can be used as a functional respiratory organ.

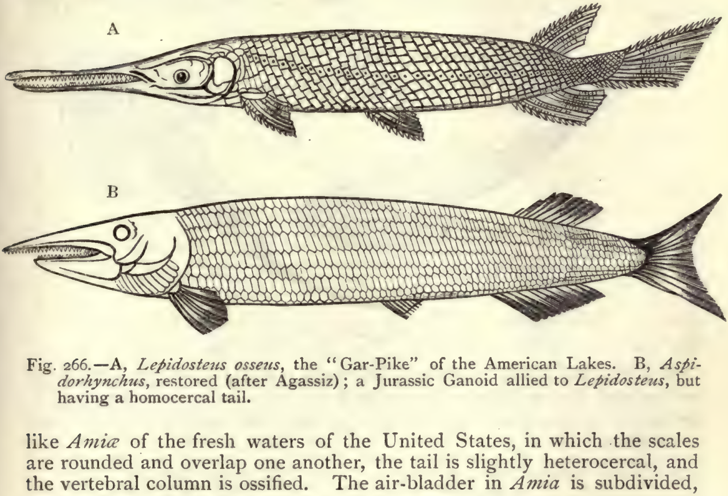

Fig. 266.—A, *Lepidosteus osseus*, the "Gar-Pike" of the American Lakes. B, *Aspidorhynchus*, restored (after Agassiz); a Jurassic Ganoid allied to *Lepidosteus*, but having a homocercal tail.

The section *Placoganoidei* includes the largest and best known of all the living Ganoid fishes—namely, the Sturgeons—and it also contains some highly singular fossil forms. The sub-order is defined by the fact that the skeleton is always imperfectly ossified, and often retains the notochord, whilst the head and more or less of the body are usually protected by large ganoid plates, which in many cases are united together at their edges by sutures. The tail is heterocercal.

The family *Chondrosteidæ*, or *Sturionidæ*, comprises the various species of Sturgeon, which are found in the seas of the northern hemisphere, whence they ascend the great rivers for the purpose of spawning. The vertebral column in the Sturgeon remains permanently in an embryonic condition. The notochord is persistent, and the vertebral centra are wanting, but the neural arches of the vertebræ reach the condition of cartilage. The mouth is destitute of teeth, and the head (fig. 253, B) is covered with an armour of large ganoid plates joined together at their edges by suture. Rows of detached ganoid plates also occur on the body. The various species of Sturgeon attain a great size, one—the Beluga—often measuring twelve or fifteen feet in length. They are commercially of considerable importance, the swimming-bladder yielding most of the *isinglass* of commerce, whilst the roe is largely employed as a delicacy under the name of *caviare.* In the Paddle-fishes (*Spatularia*) the skin is not provided with an exoskeleton. Both *Spatularia* and *Scaphirhynchus* are found in the rivers of North America; but two species of the latter have recently been discovered in Asia.

Only a few fossil forms belonging to the *Sturionidæ* are at present known; and by far the greater number of extinct Placoganoids belong to the family *Ostracostei*, established by Owen, and characterised by the fact that the head, and generally the anterior part of the trunk as well, was encased in a strong armour composed of numerous large ganoid plates, immovably joined to one another. The posterior extremity of the body was more or less completely unprotected, and, whilst the notochord was persistent, the peripheral elements of the vertebræ—namely, the neural and hæmal spines—may be ossified.

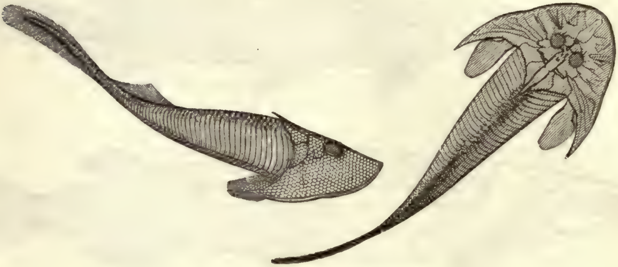

Fig 267.—*Cephalaspis Lyellii.*

The *Ostracostei*, or "Placoderms," are entirely confined to the Devonian and Upper Silurian rocks, and the most important genera comprised in the group are *Cephalaspis* (fig. 267), *Pteraspis*, *Pterichthys*, and *Coccosteus.*

CHAPTER LV.

ELASMOBRANCHII AND DIPNOI.

ORDER V. ELASMOBRANCHII (= *Selachia*, Müller; *Placoidei*, Agassiz; *Holocephali* and *Plagiostomi*, Owen).—This order includes the Sharks, Rays, and Chimæræ, and corresponds with the greater and most typical portion of the *Chondropterygidæ* or Cartilaginous fishes of Cuvier. The order is distinguished by the following characters: *The skull and lower jaw are well developed, but there are no cranial bones, and the skull consists of a single cartilaginous box, without any indication of sutures. The vertebral column is sometimes composed of distinct vertebræ,* *sometimes cartilaginous or sub-notochordal. The exoskeleton is in the form of placoid granules, tubercles, or spines. There are two pairs of fins, representing the limbs, and supported by cartilaginous fin-rays; and the ventral fins are placed far back near the anus. The pectoral arch has no clavicle. The heart consists of a single auricle and ventricle, and the bulbus arteriosus is rhythmically contractile, is provided with a special coat of striated muscular fibres, and is furnished with several transverse rows of valves. The gills are pouch-like.*

In most of the above characters, it will be seen at once that the *Elasmobranchii* agree with the Ganoid fishes, especially, as regards the structure of the heart. The following points of difference, however, require more special notice :—

I. The *exoskeleton* is what is called by Agassiz "placoid." It consists namely, of no continuous covering of scales or ganoid plates, but of more or less numerous detached grains, tubercles, or spines, composed of bony or dentinal matter, and scattered here and there in the integument. In the case of the Rays, these placoid ossifications often take a very singular shape, consisting (fig. 247, *c*) of an osseous or cartilaginous disc, from the upper surface of which springs a sharp recurved spine, composed of dentine. The so-called "shagreen" of the Dog-fishes and Sharks is composed of very small and close-set tooth-like processes (fig. 247, *d*). At other times the placoid structures are developed into "dermal defences" or "ichthyodorulites." The minute structure of these exoskeletal structures is closely or entirely similar to that of the teeth. In some cases the exoskeleton is absent.

II. The *gills* are fixed and pouch-like, and differ very materially from those of the Bony and Ganoid Fishes. In the case of the Sharks and Rays, the structure of the gills is as follows: The branchial arches are fixed, and the branchial laminæ are not only attached by their bases to the branchial arches, but are also fixed by the whole of one margin to a series of partitions, which divide the branchial chamber into a number of distinct pouches (fig. 268). Each partition, therefore, carries a series of branchial laminæ attached to each side, like the leaves of a book. By means of these septa a series of branchial sacs or pouches are formed, each of which opens internally into the pharynx by a separate slit, and communicates externally with the water by a separate aperture placed on the side of the neck (fig. 268, B). The arrangement of the gills being such, there is, of course, no gill-cover, and no branchiostegal membrane or rays. In one section of the order, however—viz., the *Holocephali*—though the *internal* structure of the gills is the same as the above, there is only a single branchial aperture or gill-slit *externally*, and this is protected by a rudimentary operculum and branchiostegal rays.

III. Another character in the *Elasmobranchii*, shared, however, by many of the Ganoids, is the structure of the intestinal canal. The intestine is extremely short; but, to compensate for this, there is a peculiar folding of the mucous membrane, constituting what is known as the "spiral valve." The mucous membrane, namely, from the pylorus to the anal aperture, is folded into a spiral reduplication, which winds in close coils round the intestine, like the turns of a screw. By this means the absorptive surface of the intestine is enormously increased, and its shortness is thus compensated for.

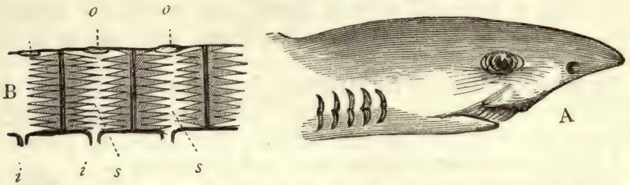

Fig. 268.—A, Head of Piked Dog-fish (*Spinax*), showing the transverse mouth on the under surface of the head, and the apertures of the gill-pouches. B, Diagram of the structure of the gill-pouches: *o o* External apertures; *i i* Apertures leading into the pharynx; *s s* Gill-sacs, containing the fixed gills.

It is to be noted that some high authorities are in favour of the view that the *Elasmobranchii* are to be regarded as a distinct class, and not as merely an order of the class *Pisces*.

The order *Elasmobranchii* is divided into two sub-orders: the *Holocephali*, characterised by the mouth being terminal in position, and there being only a single gill-slit; and the *Plagiostomi*, in which the mouth is transverse, and placed on the under surface of the head (fig. 268, A), and there are several branchial apertures on each side of the neck.

Sub-order A. Holocephali. — This sub-order includes certain curious fishes, of which the only living forms are the *Chimæridæ*. The notochord is persistent; but the neural arches and transverse processes are cartilaginous. The jaws are bony, and are covered by broad plates representing the teeth. The exoskeleton consists of placoid granules. The first ray of the anterior dorsal fin is in the form of a powerful defensive spine, like the "ichthyodorulites" of many fossil fishes. The ventral fins are abdominal, and the tail is heterocercal. There is only a single external gill-aperture, covered with a gill-cover and branchiostegal membrane; but only a small portion of the borders of the branchial laminæ is free. The mouth is placed at the extremity of the head.

The best-known living representative of the sub-order is the *Chimæra monstrosa* (fig. 269, B), commonly known as the "king of the Herrings."

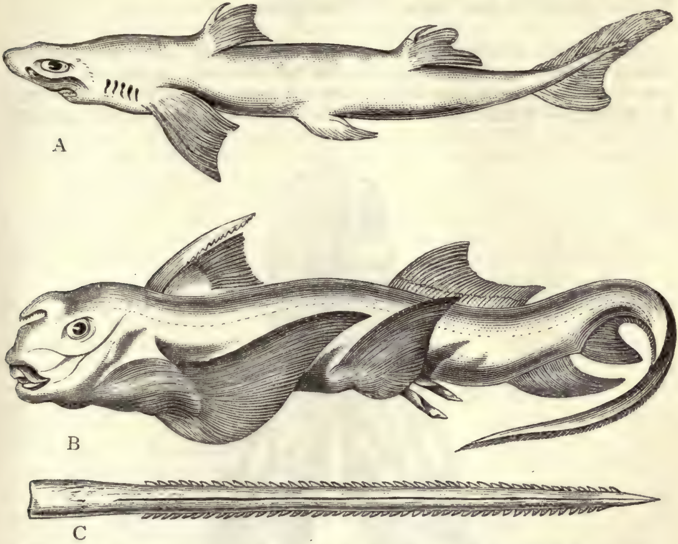

Fig. 269.—A, *Spinax acanthias,* one of the Dog-fishes. B, *Chimæra monstrosa.* C, Tail-spine of an Eagle-ray (*Myliobatis*).

In *Chimæra* there is only one apparent gill-slit, but the gills really adhere to the integument by a large portion of their borders, and there are consequently five holes communicating with the gill-slit. A rudimentary operculum is present, covered by the skin. In the closely-allied *Callorhynchus* from the South Seas, there is a large fleshy appendage at the end of the snout. In the Secondary and Tertiary Rocks are found several fossil forms, constituting the genera *Edaphodus*, *Elasmodus*, and *Ischiodus*.

SUB-ORDER B. PLAGIOSTOMI.—This sub-order is of considerably greater importance, as it includes the well-known Sharks and Rays. The vertebral centra are usually more or less ossified, and even when quite cartilaginous, the centra are marked out by distinct rings. The skull is in the form of a cartilaginous capsule, without distinct cranial bones. The mouth is transverse, and is placed on the under surface of the head (fig. 268, A). The exoskeleton consists of placoid granules, tubercles, or spines. The branchial sacs open externally by as many distinct apertures as there are sacs, and there is no operculum. A pair of tubes proceed from the pharnyx to open on the upper surface of the head by two apertures, which are termed "spiracles," and which are sometimes regarded as the homologues of the Eustachian tube and external meatus auditorius (Wyman). By means of these water can be admitted to the pharnyx, and thence to the gills.

By Professor Owen the Plagiostomi are divided into three sections, termed respectively the *Cestraphori*, the *Selachii*, and the *Batides*.

a. Cestraphori.—In this division there is a strong spine in front of each dorsal fin, and the back teeth are obtuse (fig. 270). The only living representatives of this group are the Port Jackson Shark (*Cestracion Philippi*), and some allied forms, characterised by their pavement of plate-like crushing teeth, adapted for comminuting small Molluscs and Crustaceans. They are exclusively inhabitants of the Pacific Ocean, and are remarkable for their close resemblance to a large group of extinct forms, of which the best known are the genera *Hybodus* and *Acrodus* from the Secondary rocks.

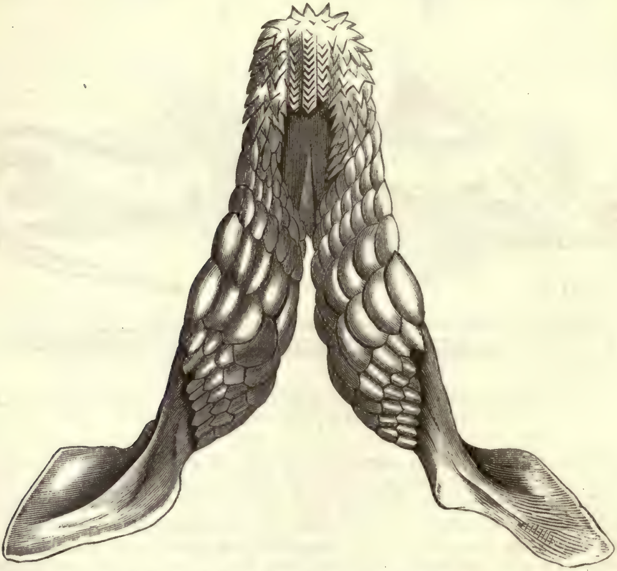

Fig. 270.—Upper jaw of Port Jackson Shark (*Cestracion*), showing the pavement of crushing teeth. One-half the natural size. (After Owen.)

b. Selachii.—This group comprises the formidable Sharks and Dogfishes, and is characterised by the lateral position of the branchiæ on the side of the neck, and by the fact that the pectoral fins have their ordinary form and position, and their anterior ends are not connected with the skull by cartilages. The skull also has a median facet for the first vertebra.

The Dog-fishes are of common occurrence in British seas, but are of little value. Their egg-cases are frequently cast up on our shores, and are familiarly known as "Mermaid's purses." The embryo possesses external branchiæ, developed both from the spiracle and the branchial arches; but these structures disappear in the course of growth. The true Sharks are not infrequently found in various European seas, but they are mostly inhabitants of warmer waters. One of the largest is the "White Shark." (*Carcharias vulgaris*), which attains a length of over thirty feet. The body in the Sharks (*Squalidæ*) is not rhomboidal, but is elongated; the nostrils are placed on the under side of the snout, and the teeth are arranged in several rows, and are in the form of compressed cones. During life, the cartilaginous jaws are so far flexible that their margins can be partially everted, thus bringing more than one row of teeth into use at one time; but the innermost rows are principally employed to replace the outer rows, when the latter are worn out.

c. Batides.—This group includes the Rays and Skates, and is distinguished by the fact that the branchial apertures are placed on the under surface of the body, forming two rows of openings a little behind the mouth. In the typical members of the group the body is flattened out so as to form a kind of rhomboidal disc (fig. 271), the greater part of which is made up of the enormously-developed pectoral fins. The pectoral fins are united by cartilage with the skull, and there is no median facet upon the occiput for articulation with the first vertebra. Upon the upper surface of the disc are the eyes and spiracles; upon the lower surface are the nostrils, mouth, and branchial apertures. The flattened bodies of the Rays, however, must be carefully distinguished from those of the Flat-fishes (*Pleuronectidæ*). In the former the flat surfaces of the body are truly the dorsal and ventral surfaces. In the latter, as before remarked, the body is flattened, not from above downwards, but from side to side, and the head is so twisted that both eyes are brought to one side of the body. The tail in the Rays is long and slender, usually armed with spines, and generally with two or three fins (the homologues of the dorsal fins). The mouth is often paved with flat teeth, of a more or less rhomboidal shape.

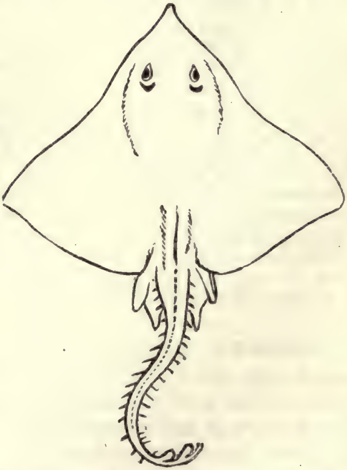
Fig. 271.—Batides. *Raia marginata*, one of the Skates. Reduced one-sixth. (After Gosse.)

The typical members of the *Batides* are the Skates and Rays, of which the common Thornback (*Raia clavata*) may be taken as a familiar example. More remarkable than the common Rays is the Electric Ray or *Torpedo*, which has the power of discharging electrical shocks if irritated. The identity of the force produced in this way with the electricity of the machine has been demonstrated by many careful experiments. The Torpedo owes its remarkable power to two special organs—the "electrical organs," which consist of two masses placed on each side of the head, and consisting each of numerous vertical gelatinous columns, separated by membranous septa, and richly furnished with nerves from the eighth pair; the whole arrangement presenting a singular resemblance to the cells of a voltaic battery. There is no doubt, however, but that the force which is expended in the production of the electricity is only nerve-force. For every equivalent of electricity which is generated, the fish loses an equivalent of nervous energy; and for this reason the production of the electric force is strictly limited by the amount of nerve-force possessed by the animal.

Other well-known members of the family are the Sting-rays (*Trygon*), the Eagle-rays (*Myliobatis*), the Horned Rays (*Cephaloptera*), and the Beaked Rays (*Rhinobatis*).

In the Saw-fish (*Pristis antiquorum*) the body has not the typical flattened form of the Rays, and the snout is elongated so as to form a long, sword-like organ, the sides of which are furnished with strong tooth-like spines. This constitutes a powerful weapon, with which the Saw-fish attacks the largest marine animals. Though principally inhabiting the sea, the Saw-fishes are not wholly marine, fresh-water forms occurring in Nicaragua and in the Philippines.

Before leaving the *Elasmobranchii*, a few words may be said as to their position in the class of fishes. From the cartilaginous nature of the endoskeleton, and the similarity between the form of their gills and those of the Lampreys and Myxinoids, the *Elasmobranchii* were long placed low down in the scale of fishes, to which also the permanently heterocercal tail conduced. When we come, however, to take into consideration the sum of all their characters, there can be little hesitation in placing the order nearly at the summit of the entire class. The nervous system, and especially the cerebral mass, is very much more highly developed proportionately than is the case with any other division of the fishes. The organs of sense are, comparatively speaking, of a very high grade of organisation, the auditory organs being more than ordinarily elaborate, the eyes being sometimes furnished with a third eyelid (*membrana nictitans*), and the nasal sacs having a very complex structure. The structure of the heart agrees with that of the Ganoids, and is a decided advance upon the heart of the more typical bony fishes. Finally, the embryo, before its exclusion from the egg, is furnished with external filamentous branchiæ, this being a decided approximation to the *Amphibia*.

ORDER VI. DIPNOI (=*Protopteri*, Owen).—This order is a small one, and includes no other living forms than Mud-fishes (*Lepidosiren* and *Ceratodus*); but it is nevertheless of great importance as exhibiting a distinct transition between the fishes and the *Amphibia*. So many, in fact, and so striking, are the points of resemblance between the two, that until recently the *Lepidosiren* (fig. 272) was always made to constitute the lowest class of the *Amphibia*. The highest authorities, however, now concur in placing it amongst the fishes, of which it constitutes, with *Ceratodus*, the highest order. The order *Dipnoi* is defined by the following characters: *The body is fish-like in shape. There is a skull with distinct cranial bones and a lower jaw, but the notochord is persistent, and there are no vertebral centra, nor an occipital condyle. The exoskeleton consists, in the living types, of horny overlapping scales, having the "cycloid" character; but* *various extinct forms have "ganoid" scales. The pectoral and ventral limbs are both present*, but have (in *Lepidosiren*) the form of awl-shaped, filiform, many-jointed organs, of which the former only have a membranous fringe inferiorly. The ventral limbs are attached close to the anus, and the pectoral arch has a clavicle; but the scapular arch is attached to the occiput. In *Ceratodus* (fig. 273) the pectoral and ventral limbs have the same form as in the Crossopterygious Ganoids. *The caudal fin is symmetrical, or, in some extinct forms, may be heterocercal. The heart has two auricles and one ventricle. The respiratory organs are twofold, consisting, on the one hand, of free filamentous gills contained in a branchial chamber, which opens externally by a single vertical gill-slit; and, on the other hand, of true lungs in the form of a double cellular air-bladder, communicating with the œsophagus by means of an air-duct or trachea. The branchiæ are supported upon branchial arches, but these are not connected with the hyoid bone; and in some cases, at any rate, rudimentary external branchiæ exist as well. The nasal sacs open posteriorly into the throat.*

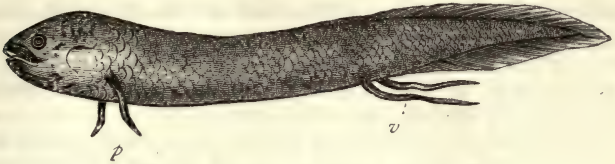

Fig. 272.—Dipnoi. *Lepidosiren annectens.*

If these characters are examined a little more minutely, it is easy to point to those in which the *Dipnoi* approach the Fishes, and to those in which they resemble the Amphibians. They resemble the fishes in the shape of the body, and in the possession of a covering of horny overlapping scales of the true cycloid character; whilst the limbs are more like those of fishes than of reptiles. The fin, also, which clothes the posterior extremity of the body, is of a decided fish-like character. The most marked piscine feature, however, is the presence of free branchiæ, attached to branchial arches, and placed in a branchial cavity, which opens internally into the pharynx by a number of fissures, and communicates externally with the outer world by means of a single vertical gill-slit.

On the other hand, the *Dipnoi* approximate to the Amphibians in the following important points: The heart consists of *three* cavities, two auricles, and a single ventricle. True lungs are present, with a trachea and glottis, returning their blood to the heart by a distinct pulmonary vein, and in every respect discharging the functions of the lungs of the higher Vertebrates. It is true that the lungs of the *Dipnoi* are merely a modification of the swim-bladder of the other fishes, but the significance of the change of function is not affected by this. Lastly, sometimes, at any rate, there are rudimentary external branchiæ placed on the side of the neck. This feature, as will be seen shortly, is characteristic of all the Amphibians, either permanently or in their immature state.

Upon the whole, then, whilst for the purposes of systematic classification the *Dipnoi* must be placed amongst the Fishes, it is not to be forgotten that many of their characters are those of a higher class, and that they may justly be looked upon as a connecting link, or transitional group, between the two great divisions of the Fishes and the Amphibians.

As regards their distribution and mode of life, two species at least of *Lepidosiren* are known—the *L. paradoxa* from the Amazon, and the *L.* (*Protopterus*) *annectens* from the Gambia. They both inhabit the waters of marshy tracts, and are able in the dry season to bury themselves in the mud, forming a kind of chamber, in which they remain dormant till the return of the rains. Recently there has been discovered in the rivers of Queensland (Australia) a fish which has been described under the name of *Ceratodus Forsteri*, and which shows itself to be very closely related to the *Lepidosiren*. This singular fish (fig. 273)—the "Jeevine" * of the natives—is from three to six feet long, and has the body covered with large cycloid scales, a species with smaller scales having been described as *C. miolepis*. The skeleton is notochordal, all the bones remaining permanently cartilaginous. There is a well-developed operculum, but—as in *Lepidosiren*—no branchiostegal rays. The tail is homocercal, and the pectoral and ventral fins are supported by a median, many-jointed, cartilaginous rod, with numerous lateral branches on each side. The heart consists

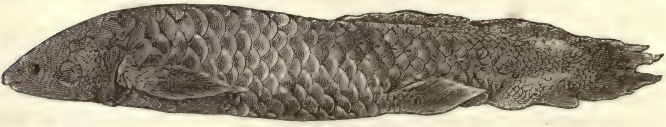

Fig. 273.—*Ceratodus Forsteri*, the Australian Mud-fish, reduced in size.

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* The name of "Barramunda" seems to have been given to *Ceratodus* by error, the native Australians apparently calling it the "Jeevine" or "Teebine."

of a single auricle and ventricle, with a "Ganoid" bulbus arteriosus. There are five branchial arches, of the Teleostean type, but cartilaginous. The swim-bladder is single, composed of two symmetrical halves, cellular in structure, with a pneumatic duct and glottis, as in *Lepidosiren*. The intestine has a spiral valve, and there are no pyloric cæca. There are two molar teeth in each jaw, having the form of flattened undulated plates of bone, singularly like the teeth of *Ceratodus* from the Trias (fig. 274). The *Ceratodi* employ these crushing teeth in the mastication of vegetable matter, upon which they feed; and they are stated to leave the streams which they inhabit, at night time, in order to betake themselves to the marshy flats in the vicinity, where they obtain an abundant supply of food.

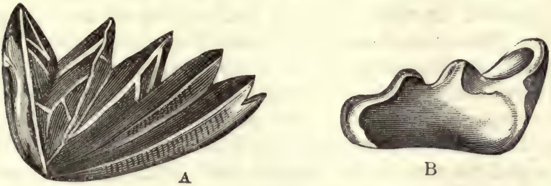

Fig. 274.—A, Dental plate of *Ceratodus serratus*, Keuper. B, Dental plate of *Ceratodus altus*, Keuper. (After Agassiz.)

The genera *Lepidosiren* (with *Protopterus*) and *Ceratodus* comprise the few living species of *Dipnoi*, and constitute a special division (*Sirenoidei*) characterised by the possession of horny cycloidal scales, a symmetrically divided caudal fin, and an undivided dorsal fin. There are, however, a few Palæozoic genera of *Dipnoi*—of which the most important are *Dipterus* and *Ctenodus*—which constitute a distinct sub-order (*Ctenodipterini*), characterised by their enamelled scales, their heterocercal tails, and their possession of two dorsal fins.

Upon the whole, Dr Günther concludes that the *Dipnoi* are to be regarded as a simple sub-order of Ganoids, and that the entire order *Ganoidei* may be united with *Elasmobranchii* into a single order, called *Palæichthyes*, characterised by having a "heart, with a contractile bulbus arteriosus, intestine, with a spiral valve, and optic nerves non-decussating."

CHAPTER LVI.

DISTRIBUTION OF FISHES IN TIME.

THE geological history of fishes presents some points of peculiar interest. Of all the classes of the great sub-kingdom *Vertebrata,* the fishes are the lowest in point of organisation. It might therefore have been reasonably expected that they would present us with the first indications of vertebrate life upon the globe; and such is indeed the case. After passing through the enormous group of deposits known as the Laurentian, Huronian, Cambrian, and Lower Silurian formations—representing an immense lapse of time, during which, so far as we yet know with certainty, and leaving the "Conodonts" out of sight, no vertebrate animal had been created—we find in the Upper Silurian rocks the first traces of fish. The earliest of these, in Britain, are found in the base of the Ludlow rocks (Lower Ludlow Shale), and belong to the Placoganoid genus *Pteraspis.* Also in the Ludlow rocks, but at the summit of their upper division, are found fin-spines and shagreen, probably belonging to Cestraciont fishes—that is to say, to fishes of as high a grade of organisation as the *Elasmobranchii.* So abundant are the remains of fishes in the next great geological epoch—namely, the Devonian or Old Red Sandstone—that this period has frequently been designated the "Age of Fishes." Most of the fishes of the Old Red Sandstone belong to the order *Ganoidei*, but the order *Dipnoi* appears to be also represented. In the Carboniferous and Permian rocks which close the Palæozoic period, most of the fishes are still Ganoid, but the former contain the remains of many Elasmobranchii. At the close of the Palæozoic and the commencement of the Mesozoic epoch, the Ganoid fishes begin to lose that predominant position which they before occupied, though they continue to be represented through the whole of the Mesozoic and Kainozoic periods up to the present day. The Ganoids, therefore, are an instance of a family which has endured through the greater part of geological time, but which early attained its maximum, and has been slowly dying out ever since. Towards the close of the Mesozoic period (in the Cretaceous period) the great family of the Teleostean or Bony Fishes is for the first time known certainly to have made its appearance. The families of the *Marsipobranchii* and *Pharyngobranchii* have not left, so far as is known, any traces of their existence in past time. Judging from analogy, however, it is highly probable that both of these must have had a vast antiquity, and it is not impossible that the so-called "Conodonts" of the Palæozoic period may yet be shown to be the teeth of fishes allied to the Lampreys.

Leaving these unrepresented orders out of consideration, the following are the chief facts as to the geological distribution of the other great groups :—

I. *Ganoidei.*—As far as is yet known with certainty, the oldest representatives of the fishes belong to this order. The order is represented, namely, in the Upper Silurian rocks by the remains of at least four genera. In the Devonian rocks, or Old Red Sandstone, the Ganoids attain their maximum both in point of numbers and development. The Placoganoid division of the order is represented by the singular genera *Pterichthys*, *Cephalaspis* (fig. 267), *Pteraspis*, and *Coccosteus*. The Lepidoganoid division of the order is now also abundantly represented for the first time, the genera *Dipterus*, *Osteolepis* (fig. 265), *Glyptolepis*, *Holoptychius*, *Diplacanthus*, and many others, belonging to this section. As regards the further distribution of the Placoganoids, the section of the *Ostracostei*, characterised by the great development of the cephalic buckler, appears to have died out at the close of the Devonian period. The other section, however—namely, that of the *Sturionidæ*—is represented in the Liassic period (*Mesozoic*) by the genus *Chondrosteus*, and in the Eocene (*Kainozoic*) by a true Sturgeon, the *Acipenser toliapicus*.

The Lepidoganoids continue from the period of the Old Red in great profusion, and they are represented by very many genera in the Carboniferous and Permian rocks. In the earlier portion of the Mesozoic period—*i.e.*, in the Lias and Trias—they are still represented, but all the forms are as yet heterocercal. In the Oolitic rocks, for the first time, Lepidoganoids with homocercal tails (fig. 266, B) appear, and they continue to be represented up to the present day.

II. *Elasmobranchii.*—Like the *Ganoidei*, the great order of the Sharks and Rays is one of vast antiquity. At the top of the Upper Ludlow rocks, or at the close of the Upper Silurian epoch, there have been discovered the remains of undoubted Plagiostomous fishes, mostly nearly allied to the existing Port Jackson Shark (*Cestracion Philippi*). These remains consist chiefly of defensive spines, which formed the first rays in the dorsal fins, and upon these the genus *Onchus* has been founded. Besides these there have been found portions of skin or "shagreen," with little placoid tubercles, like the skin of a living shark. These have been referred to the genus *Sphagodus.* They are the earliest known remains of Plagiostomous fishes, and, with the exception of the few remains from the Lower Ludlow rocks, they are the earliest known remains of fishes in the stratified series. The discovery of these remains, at that time the earliest known traces of Vertebrate life, is due to the genius of Sir Roderick Murchison, the author of 'Siluria.'

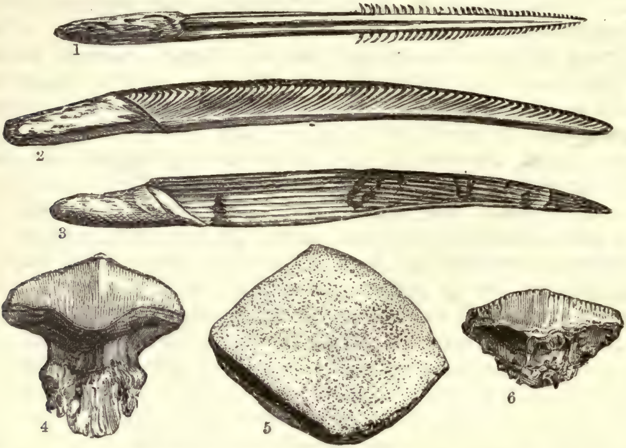

Fig. 275.—1. Spine of *Pleuracanthus* (one of the Rays); 2. *Gyracanthus;* 3. *Ctenacanthus;* 4. Tooth of *Petalodus;* 5. *Psammodus;* 6. *Ctenoptychius.* All from the Carboniferous rocks.

Most of the fossil *Elasmobranchii* belong to the division *Cestraphori* of Owen, so called because they are provided with the large fin-spines, which are known to geologists as "ichthyodorulites." The two families of this division—the Cestracionts and Hybodonts—are largely represented in past time, the former chiefly in the Palæozoic period, the latter chiefly in the Mesozoic rocks. Above (fig. 275) is an illustration of the "ichthyodorulites" and teeth of some of the Palæozoic *Cestraphori.*

The true Sharks are represented in the later Mesozoic deposits (*e.g.*, by teeth of *Notidanus* in the Oolites); but they are chiefly Tertiary. The teeth of *Odontaspis*, *Galeocerdo*, and *Carcharodon*, are good examples from the Eocene. The true Rays are older than the true Sharks, the Carboniferous fossil, *Pleuracanthus*, being probably the spine of a Ray (fig. 275). Numerous remains of Rays, chiefly in the form of the pavement-like teeth, are known, both from the Secondary and Tertiary rocks. The last division of the *Elasmobranchii*—viz., that of the *Holocephali*—is poorly represented in past time by Mesozoic and Kainozoic genera such as *Ischiodus*, *Elasmodus*, *Ganodus*, and *Edaphodus*.

III. The order of the *Dipnoi*, until of late years, was not known to be represented in past time at all. By the discovery, however, of the Queensland *Ceratodi*, it is now known that the Triassic and Jurassic teeth (fig. 274), upon which the genus *Ceratodus* was originally founded by Agassiz, are truly referable to Dipnoous fishes, mostly closely allied to the living forms. No other form of the Sirenoid division of the *Dipnoi* is known save *Ceratodus*; but the *Ctenodipterine* division of the order is well represented in past time by the *Dipterus* of the Devonian, the *Ctenodus* of the Devonian and Carboniferous, and some other less important genera.

IV. The *Bony* or *Teleostean* fishes do not make their appearance sooner than the Cretaceous period—that is, towards the close of the Mesozoic epoch. From this time on, however, Bony fishes with cycloid or ctenoid scales are the chief representatives of the whole class, and the order appears to have attained its maximum in our present seas.

LITERATURE.

[In addition to many of the systematic treatises quoted in the list of works dealing with the Vertebrata generally (p. 459) the student of recent and fossil fishes may consult the following:—]

1. "Histoire Naturelle des Poissons." Cuvier and Valenciennes. 1828-49.
2. "Catalogue of Fishes in the Collection of the British Museum." Günther. (Begun in 1859.)
3. "Allgemeine Naturgeschichte der Fische." Bloch. 1782-95.
4. "Atlas Ichthyologique." Bleecker. 1861-76.
5. "History of British Fishes." Yarrell, 2d ed. 1836-60.
6. "History of the Fishes of the British Islands." Couch. 1865.
7. "Histoire Naturelle des Poissons d'eau douce de l'Europe Centrale." Louis Agassiz. 1839-42.
8. "Anatomie des Salmones." Agassiz and Vogt. 1845.
9. "Histoire Naturelle des Poissons." Lacepède. 1756-1826.
10. "Lehrbuch der Zootomie." Von Siebold und Stannius.
11. Article "Fishes" in Todd's 'Cyclopædia of Anat. and Phys.' 1847. Rymer Jones.
12. "Systematische Beschreibung der Plagiostomen." Müller und Henle. 1841.
13. "Anatomie der Myxinoiden." J. Müller. 'Abhandl. der Berlin Akad.' 1835-45.
14. "Ueber den Bau und die Grenzen der Ganoiden." J. Müller. Ibid. 1846.

15. "Ueber den Bau und die Lebens-erscheinungen des Branchiostoma lubricum." J. Müller. Ibid. 1844.
16. "Beiträge zur Kenntniss der natürlichen Familien der Fische." J. Müller. 'Wiegmann's Archiv für Naturgeschichte.' 1843.
17. "Entwickelung des Amphioxus." Kowalewsky. 'Mém. de l'Acad. Imp. des Sci. de St Petersbourg.' 1867.
18. "Description of Lepidosiren annectens." Owen. 'Trans. Linn. Soc.' 1840.
19. "Description of Ceratodus." Günther. 'Phil. Trans.' 1872.
20. "Ceratodus and its Place in the System." Günther. 'Ann. and Mag. Nat. Hist.' 1871.
21. "Ceratodus Forsteri." Krefft. 'Proc. Zool. Soc.' 1870.
22. "Structure of Ceratodus." Huxley. 'Proc. Zool. Soc.' 1876.
23. "Sirenoid and Crossopterygian Ganoids." Miall. 'Palæontographical Society.' 1878.
24. "On the Genus Dipterus," &c. Traquair. 'Ann. and Mag. Nat. Hist.,' ser. 5, vol. ii. 1878.
25. "On the Structure and Affinities of Tristichopterus alatus." Traquair. 'Trans. Roy. Soc. Edin.,' vol. xxvii. 1875.
26. "Monograph of the Ganoid Fishes of the British Carboniferous Formations (Palæoniscidæ)." Traquair. 'Palæontographical Society.' 1877.
27. "Entwickelungsgeschichte der Thiere." Von Baer. 1837.
28. "Odontography." Owen. 1840-45.
29. "Die Panzer-welse des Hof-Naturalien-Cabinet in Wien." Kner. 1853-59.
30. "Recherches sur les Poissons Fossiles." Agassiz. 1833-43.
31. "Monographie des Poissons fossiles du Vieux Grès Rouge." Agassiz. 1844.
32. "Fossilen Fische des Silurischen Systems." Pander. 1856.
33. "Die Placodermen." Pander. 1857.
34. "Die Ctenodipterinen des Devonischen Systems." Pander. 1858.
35. "Die Saurodipterinen, Dendrodonten, Glyptolepiden, und Cheirolepiden des Devonischen Systems." Pander. 1860.
36. "Essay upon the Systematic Arrangement of the Fishes of the Devonian Epoch." Huxley. 'Mem. Geol. Survey of Great Britain.' Decade X. 1861.
37. "Structure of Crossopterygian Ganoids." Huxley. Ibid. Decade XII. 1866.
38. "Monograph of the Fishes of the Old Red Sandstone of Britain." (Cephalaspidæ). Powrie and Ray Lankester. 'Pal. Soc.' 1868-70.
39. "The Old Red Sandstone." Hugh Miller. 1857.
40. "Palæontology of Ohio." (Carboniferous and Devonian Fishes). Newberry. 1873 and 1875.
41. "Monograph on the Development of Elasmobranch Fishes." F. M. Balfour. 1878.

DIVISION I.—ICHTHYOPSIDA.

CHAPTER LVII.

CLASS II.—AMPHIBIA.

THE class *Amphibia* comprises the Frogs and Toads, the Salamandroids, the *Cæciliæ*, and the extinct *Labyrinthodonts*, and may be briefly defined as follows:—As is the case with the Fishes, the embryo is not furnished with an amnion, and the urinary bladder is the only representative of the allantois. As in Fishes, also, *branchiæ or filaments adapted for breathing air dissolved in water are always developed upon the visceral arches for a longer or shorter time.* On the other hand, the Amphibians differ from the Fishes in the fact that *true lungs are always present in the adult; the limbs are never converted into fins; and when median fins are present, as is sometimes the case, these are never furnished with fin-rays.* The limbs, when present, exhibit in their skeleton the same parts as do the limbs of the higher Vertebrates. *The skull always articulates with the vertebral column by means of two occipital condyles. The heart consists of two auricles and a single ventricle. The nasal sacs communicate posteriorly with the pharynx; and the rectum, ureters, and ducts of the reproductive organs open into a common chamber or "cloaca."*

The great and distinguishing character of the *Amphibia* is the fact that they undergo a *metamorphosis* (rarely concealed or inconspicuous) after their exclusion from the egg. They commence life as water-breathing larvæ, provided with gills or branchiæ; but in their adult state they invariably possess lungs—the branchiæ in the higher forms disappearing when the lungs are developed—but being in other cases permanently retained throughout life.

In the earliest embryonic condition the branchiæ are *external*, placed on the side of the neck, and not situated in an internal chamber, as in Fishes. In some cases the external branchiæ only are present, and they are, in any case, the gills which are retained in those forms in which the branchiæ are permanent (*Perennibranchiata*). In the tailless Amphibians (*Anoura*), with hardly an exception, two sets of gills are developed—an external set, which is very soon lost, and an internal set, which is retained for a longer or shorter period. As maturity is approached, true lungs adapted for breathing air are developed. The development, however, of the lungs varies with the completeness with which aerial respiration has to be accomplished; being highest in those forms which lose their gills when grown up (*Caducibranchiata*), and lowest in those in which the branchiæ are retained throughout life (*Perennibranchiata*); while even in the highest forms of the class the structure of the lung is very simple.

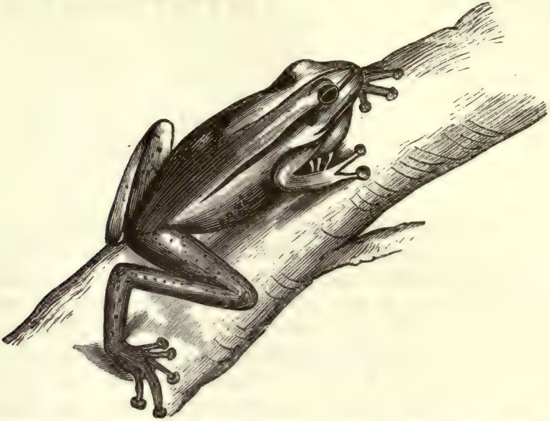

Fig. 276.—*Anoura. Hyla leucotænia*, one of the Tree-frogs (after Günther).

In accordance with the change from an aquatic or branchial to a more or less completely aerial or pulmonary mode of respiration, considerable changes are effected in the course and distribution of the blood-vessels. In the larval condition, when the respiration is entirely effected by means of the gills, the circulation is carried on very much as it is in Fishes. The heart is composed of a single auricle and ventricle, and the blood is propelled through a bulbus arteriosus and branchial artery to the gills. The aerated blood is then collected in the branchial veins, and instead of being returned to the heart, is forthwith propelled to all parts of the body, the descending aorta being formed out of the branchial veins. At this stage, therefore, the heart is a branchial one, and the single contraction of the heart is sufficient to drive the blood through both the branchial and systemic circulations, just as we saw was permanently the case with all the Fishes except the *Dipnoi*. The pulmonary arteries are at first very small, and take their origin from the last pair of branchial arteries. When the lungs, however, are developed, and the respiration commences to be aerial, the pulmonary arteries increase proportionately in size, and more and more blood is gradually diverted from the gills and carried to the lungs, so that the branchiæ suffer a proportionate diminution in size. In those Amphibians in which branchiæ are permanently retained (*Perennibranchiata*), this state of affairs remains throughout life—that is to say, a portion of the venous blood is sent by the pulmonary artery to the lungs, and a portion goes to the gills. In those Amphibians, however, in which the adult breathes by lungs alone (*Caducibranchiata*), further changes ensue. In these the pulmonary arteries increase so much in size that they ultimately divert all the blood from the branchiæ, and these organs, having fulfilled their temporary function, become atrophied and disappear. The vessels which return the aerated blood from the lungs (the pulmonary veins) increase in size proportionately with their increased work, and ultimately come to open into a second auricle formed at their point of union. The heart, therefore, of the *Amphibia* in their adult state consists of *two* auricles and a common ventricle. The right auricle receives the venous blood from the body, and the left receives the arterial blood from the lungs, and both empty their contents into the single ventricle. As in Reptiles, therefore, the ventricular cavity of the heart in adult Amphibians contains a mixed fluid, partly venous and partly arterial, and from this both the body and the lungs are supplied with blood.

The larval Amphibians are furnished with a more or less extensively developed caudal appendage or tail, which may or may not be retained throughout life. In the so-called "tailed" Amphibians, such as the Newts, the larval tail is permanently retained (fig. 277); whereas in the "Tail-less" forms, such as the Frogs (fig. 276), the tail is absorbed before maturity is attained. In a few cases, it seems questionable if the larvæ possess branchiæ, and there is no metamorphosis properly so called, since the young animal resembles the adult in all except size almost immediately after exclusion from the egg. In one of these cases (*Hylodes*) the larval tail appears to officiate as a breathing-organ, before emergence from the egg, but is absorbed within the first day after hatching. In other cases, again—*e.g.*, in *Pipa* and *Nototrema*—though a metamorphosis takes place, this is completed before the young animal begins to lead a free existence.

The endoskeleton of the *Amphibia* is generally well ossified, and the skull possesses two occipital condyles. The vertebræ are biconcave or amphicœlous (as in Fishes) in *Proteus*, *Cæcilians*, and most of the extinct *Labyrinthodonts*. In the Salamanders and Surinam Toads the vertebræ are opisthocœlous, but most of the other Amphibians have procœlous vertebræ. The length of the vertebral column is greatly reduced in the tail-less forms, and the number of vertebræ is correspondingly small. The sacrum is seldom composed of more than one vertebra, and there are often no separately-ossified ribs. In the Tailed Amphibians and the Cæcilians, however, there are well-developed ribs, which are never supplemented in front by sternal ribs, though a cartilaginous or partially-ossified sternum may be present.

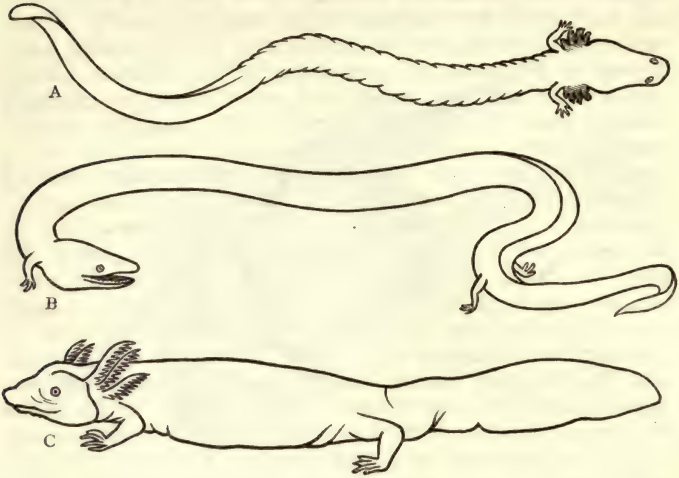

Fig. 277.—Tailed Amphibians. A, *Siren lacertina*; B, *Amphiuma*, showing the four minute limbs; C, *Menobranchus maculatus*. (After Mivart.)

Limbs may be entirely wanting (as in the Cæcilians and some of the Labyrinthodonts); but all the other members of the class possess both pairs of limbs, with the exception of the genus *Siren*, in which the pelvic limbs are wanting (fig. 277).

The skin is mostly soft, moist, and richly provided with glands; the Cæcilians have mostly small rounded horny scales imbedded in the integument; and the extinct Labyrinthodonts possessed a ventral armour of bony scales. Integumentary ossifications are also developed in some other cases (*e.g.*, *Ceratophrys*).

As regards the digestive system of the *Amphibia* there is little to say, except that the rectum opens, as it does in Reptiles, into a common chamber or "cloaca," into which are also discharged the secretions of the kidneys and generative organs. A liver, gall-bladder, spleen, and pancreas are always present. Singular pulsating cavities, belonging to the lymphatic system, and known as "lymph-hearts," are also present in the higher Amphibians. The alimentary canal is much longer in the larval Amphibians than in the adult. A tongue may or may not be present, but there are no salivary glands. Teeth are usually developed in the vomer, præmaxillæ, maxillæ, and mandible, and are generally disposed in the upper jaw in the form of two concentric semicircles. In the larvæ of the Frogs and Toads the front of the maxillæ and mandible are encased in a horny beak.

A urinary bladder is present, opening into the cloaca, and there are well-developed kidneys. The ducts of the reproductive organs communicate with the urinary ducts. The ova are usually impregnated outside the body; but internal impregnation occurs in some of the *Urodela*.

CHAPTER LVIII.

ORDERS OF AMPHIBIA.

THE *Amphibia* are usually divided by modern writers into four orders, the old order *Lepidota*, comprising the *Mud Fishes*, being now placed at the head of the Fishes, under the name of *Dipnoi*. Whilst there is a general agreement as to the number and characters of the Amphibian orders, the names employed to designate them are very various, and it really matters little which are adopted.

ORDER I. OPHIOMORPHA, Owen (= *Gymnophiona*, Huxley; *Apoda*, *Peromela*, *Ophidobatrachia*):—*Serpentiform or vermiform Amphibians, without limbs; anus terminal; skin mostly with horny scales imbedded in it. Eyes rudimentary or absent.*

This is a small order, including only certain snake-like, vermiform animals (fig. 278) which are found in various tropical countries, burrowing in marshy ground, something like gigantic earth-worms; while some of them seem to temporarily inhabit water. They form the family *Cæciliadæ* (so called by Linnæus from their supposed blindness), and are characterised by their snake-like form, and by having the anus placed almost at the extremity of the body. The body is cylindrical and worm-like, and is completely destitute of limbs. The skin is glandular, naked, and viscous, thrown into numerous folds, and containing numerous delicate, rounded, horny scales, which are dermal in their character, and are wanting in *Siphonops annulatus*. The mandibular rami are short, and are united in front by a symphysis. The teeth are long, sharp, and generally recurved; and a row of palatine teeth forms a concentric series with the maxillary teeth. The tongue is fleshy, fixed to the concavity of the lower jaw, and not protrusible (fig. 278). The ribs are numerous, but there is no sternum. The adult possesses lungs, one of which is smaller than the other, and the nose opens behind into the mouth. The eyes are rudimentary, nearly concealed beneath the skin, or altogether wanting.

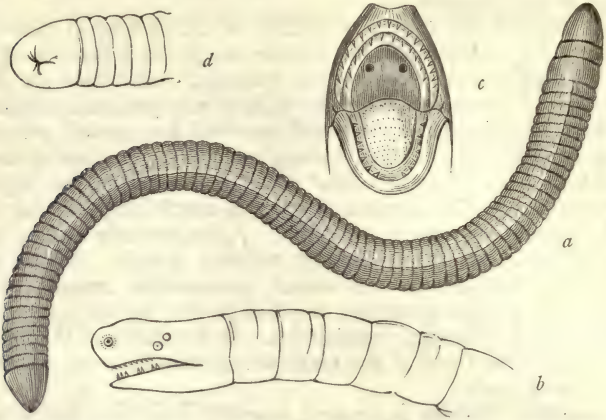

Fig. 278.—Ophiomorpha. *a Siphonops annulatus*, one of the Cæcilians, much reduced: *b* Head; *c* Mouth, showing the tongue, teeth, and internal openings of the nostrils; *d* Tail and cloacal aperture. (After Dumeril and Bibron.)

The position of the *Cæciliæ* was long doubtful; but their Amphibian character was ultimately proved by the discovery that whilst the adult breathes by lungs, the young, in some cases, possess internal branchiæ, communicating with the external world by a branchial aperture on each side of the neck; while in other cases the adult is viviparous, and the young, prior to birth, are furnished with vesicular external branchiæ placed on the side of the neck. In addition to the presence of branchiæ in the larva, the Cæcilians are further connected with the *Amphibia* by their possession of a double occipital condyle and of a glandular skin; whilst they approach the Fishes in generally having small horny scales embedded in the integument, and in the fact that the vertebræ are amphicœlous, and the cavities formed by their apposition are filled with the gelatinous remains of the notochord. As regards their distribution in space, the species of *Cæcilia* are found in India, Africa, and South America; *Siphonops* and *Rhinatrema* are exclusively American; and *Epicrium* is exclusively Asiatic.

ORDER II. URODELA (=*Ichthyomorpha*, Owen; *Saurobatrachia*).—This order is commonly spoken of collectively as that of the "Tailed" Amphibians, from the fact that the larval tail is always retained in the adult. The *Urodela* are characterised by having the *skin naked, and* (except in *Salamandra unguiculata*) *destitute of any exoskeleton. The body is elongated posteriorly to form a compressed or cylindrical tail, which is permanently retained throughout life. The dorsal vertebræ are biconcave* (*amphicœlous*), *or concave behind and convex in front* (*opisthocœlous*), *and they have short ribs attached to the transverse processes. The bones of the fore-arm* (*radius and ulna*) *on the one hand, and those of the shank* (*tibia and fibula*) *on the other, are not anchylosed to form single bones.*

In one section of the order—formerly called *Amphipneusta*—the gills are retained throughout life, and the animal is therefore "perennibranchiate." In this section are the *Proteus*, *Siren*, *Menobranchus*, &c. In the remaining members of the order the gills disappear at maturity, and the animal is therefore "caducibranchiate." In this section are the Land and Water Salamanders. One form, however—the Axolotl of Mexico—appears to be sometimes caducibranchiate, though generally perennibranchiate. The genera *Amphiuma* and *Menopoma*, also, exhibit a partially intermediate state of parts;

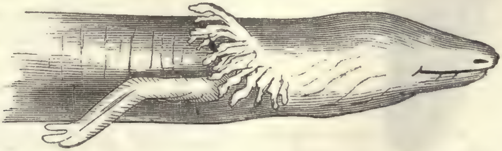

Fig. 279.—Head and fore-part of the body of *Proteus anguinus*, showing the external branchiæ and tridactylous fore-limb.

for though they lose their branchiæ when adult, they nevertheless retain the branchial apertures behind the head.

Of the perennibranchiate *Urodela*, one of the best known is the singular *Proteus* (*Hypochthon*) *anguinus* (fig. 279), which is only found inhabiting pools in certain caves in Illyria and Dalmatia. It is of a pale flesh-colour, or nearly white, with three branchial tufts on each side of the neck, while the gill-slits are also persistent. It attains a length of about a foot, and has two pairs of weak limbs, of which the anterior have three toes, and the posterior only two. From its habitat, the power of vision must be quite unnecessary, and, as a matter of fact, the eyes are altogether rudimentary, and are covered by the skin. Several varieties of *Proteus* are known, and the one figured above has been described as a distinct species (*P. xanthostictus*). The blood-corpuscles in *Proteus* are oval in shape, and are larger than those of any other vertebrate animal.

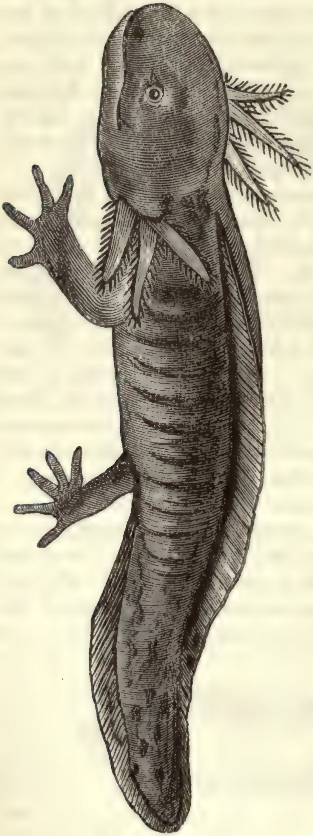

Fig. 280.—The Axolotl (*Siredon pisciforme*)—after Tegetmeier. The ordinary form, with persistent branchiæ.

Of the *Sirenidæ*, the most familiar are the Sirens and the Axolotls. The Siren, or Mud-eel (fig. 277, A), is found abundantly in the rice-swamps of South Carolina, and attains a length of three feet. The branchiæ are persistent, and the hinder pair of legs wholly wanting. Two other species are known, but they are likewise confined to North America.

The Mexican Axolotl (*Siredon pisciforme*, fig. 280) is a native of the Mexican lakes, and attains a length of about a foot or fourteen inches. It possesses both pairs of limbs, the anterior pair having four toes, and the hinder pair five toes.

As ordinarily known in its native country, the Axolotl is certainly perennibranchiate, and they breed in this condition freely. There is no doubt, however, that individual specimens may lose their gills, without thereby suffering any apparent change, except it be one of colour. The Axolotl, therefore, is in the singular position of being sometimes "caducibranchiate," whilst it is ordinarily "perennibranchiate." * Nearly allied to the Axolotl is the *Menobranchus* (fig. 277, C) of North America, in which the branchiæ are persistent. *Amphiuma* (fig. 277, B) and *Menopoma*, as already remarked, differ from the forms just mentioned in losing the gills when adult, but in retaining the external branchial apertures on the side of the neck. The species of *Amphiuma* are North American, and have both pairs of limbs, though these are of very small size.

The species of *Menopoma*, as now restricted, are also confined to the fresh waters of the United States, and likewise possess both pairs of limbs. The Giant-salamanders of Java form the genus *Sieboldia* or *Cryptobranchus*, and differ from *Menopoma* chiefly in the fact that the gill-slits are closed in the adult. They reach a length of several feet, and are the nearest living allies of the extinct *Andrias* of the Miocene Tertiary.

In the second section of the *Urodela*, comprising those forms in which the gills are caducous, and both pairs of limbs are always present, are the Water-salamanders or Tritons, and the Land-salamanders. The Tritons are the only examples of the aquatic Salamanders which occur in Britain, and every one, probably, is acquainted with the common Newt.

The Water-salamanders or Newts (fig. 281) are distinguished from the terrestrial forms by being furnished with a compressed fish-like tail, and by being strictly oviparous. The larvæ are tadpole-like, with external branchiæ, which they retain till about the third month. The adult is destitute of gills, and breathes by lungs alone, but the larval tail is retained throughout the life of the animal. The tongue is small, free, and pointed behind, and there are two rows of palatine teeth. The fore-feet are four-toed, the hind-feet five-toed; and the males have a crest on the back and tail.

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* Professor Marsh of New Haven has shown that the *Siredon lichenoides* of the western States of America, when kept in confinement, loses its gills, and dorsal and caudal fins, whilst it changes much in colour, and undergoes various minor modifications in structure. Its habits, also, become less aquatic, and it becomes apparently absolutely identical with *Amblystoma mavortium*, a Salamandroid. This discovery has thrown considerable doubt upon the value of the distinction between perennibranchiate and caducibranchiate Amphibians, and has rendered it probable that all the species of *Siredon* are merely larval Salamanders, as long ago suspected by Cuvier. At the same time, the Axolotls certainly breed freely whilst in possession of their branchiæ, and there is as yet no proof that they lose their gills whilst in a state of nature. It is, in fact, still uncertain whether all the species of *Siredon* are merely larval stages of *Amblystoma*, or whether all the *Amblystomæ* possess a larval *Siredon*-stage.

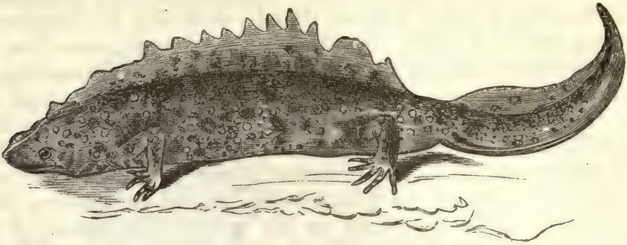

Fig. 281.—Great Water-newt (*Triton cristatus*)—after Bell.

The development of the Newts is so like that of the Frogs that it is unnecessary to dilate further upon it here; but there are these two points of difference to be noticed: 1*stly*, That the embryonic tail is not cast off in the adult; and, 2*dly*, That the fore-limbs appear externally sooner than the hind-limbs—the reverse of this being the case amongst the *Anoura*.

The Land-salamanders form the genus *Salamandra*, and are distinguished from their aquatic brethren by having a cylindrical instead of a compressed tail, and by bringing forth their young alive, or by being ovo-viviparous, in which case the larvæ have sometimes shed their external branchiæ prior to birth. The head is thick, the tongue broad, and the palatine teeth in two long series. The skin is warty, with many glands secreting a watery fluid. The best-known species is the *S. maculosa* of Southern Europe. Another species (*S. alpina*) lives upon lofty mountains. The Salamanders of the Old World are represented in North America by various species of *Amblystoma*.

ORDER III. ANOURA (= *Batrachia*, Huxley; *Theriomorpha*, Owen; *Chelonobatrachia*, *Batrachia salientia*, &c.)—This order includes the Frogs and Toads, and is characterised by the following points: *The adult is destitute of both gills and tail, both of which structures exist in the larva, whilst the two pairs of limbs are always present. The skin is soft, and there are rarely any traces of an exoskeleton. The dorsal vertebræ are "procœlous," or concave in front, and are furnished with long transverse processes, which take the place of ribs, which are only present in a rudimentary form. The radius and ulna in the fore-limb, and the tibia and fibula in the hind-limb, are anchylosed to form single* *bones* (fig. 282). *The mouth is sometimes edentulous, but the upper jaw has usually small teeth, and the lower jaw sometimes.*

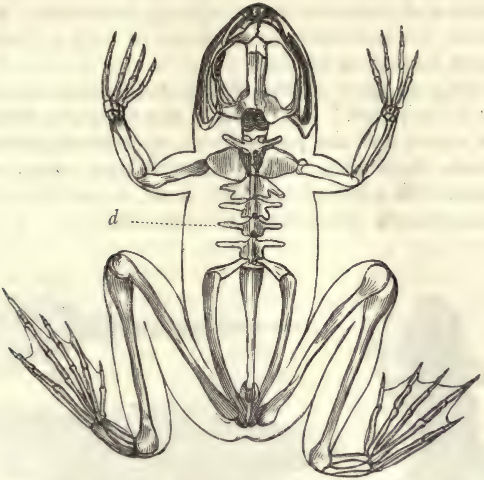

Fig. 282.—Skeleton of the common Frog (*Rana temporaria*). *d* Dorsal vertebræ, with long transverse processes.

The hind-limbs usually have the digits webbed for swimming, and are generally much larger and longer than the fore-limbs. The vertebral column is short (of ten vertebræ in the Frogs, but only eight in *Pipa*). The tongue is soft and fleshy, not supported by an os hyoides, but fixed to the symphysis of the lower jaw in front.

In the adult *Anoura*, respiration is purely aerial, and is carried on by means of lungs, which are, comparatively speaking, well developed. As there are no movable ribs by which the thoracic cavity can be expanded, the process of respiration is somewhat peculiar. The animal first closes its mouth, and fills the whole buccal cavity with air taken in through the nostrils. The posterior nares are then closed, and by the contraction of the muscles of the cheeks and pharynx the inspired air is forcibly driven into the windpipe through the open glottis. The process, in fact, is one of swallowing; and it is possible to suffocate a frog simply by holding its mouth open, and thereby preventing the performance of the above-mentioned actions. There can be no doubt, also, that the skin in these animals plays a very important part in the aeration of the blood, and that the frogs especially can carry on their respiration cutaneously, without the assistance of the lungs, for a very lengthened period. This undoubted fact, however, should not lead to any credence being given to the often-repeated stories of the occurrence of frogs and toads in cavities in solid rock, no authenticated instance of such a phenomenon being as yet known to science.

The young or larvæ of the Frogs and Toads are familiarly known as "Tadpoles." The ova of the Frog are deposited in masses in water, and the young form, upon exclusion from the egg, presents itself as a "tailed" Amphibian, completely fish-like in form, with a broad rounded head, a sac-like abdomen, and a compressed swimming-tail (fig. 283, *a*). Behind the mouth are placed little "holders" or organs of adhesion; and the upper and lower jaws acquire horny sheaths and constitute a kind of beak. There are at first two sets of gills, one external and the other internal. The external branchiæ (fig. 283, *a*) have the form of filaments attached to the side of the neck, and they disappear very shortly after birth. The internal branchiæ are attached to cartilaginous arches, which are connected with the hyoid bone, and they are contained in a gill-cavity, protected by a flap of integument, which differs from the gill-cover of fishes in never developing any opercular bones or branchiostegal rays. Within the branchial chamber thus formed the fore-limbs are budded forth, but the hind-limbs are the first to appear externally, instead of the fore-limbs as

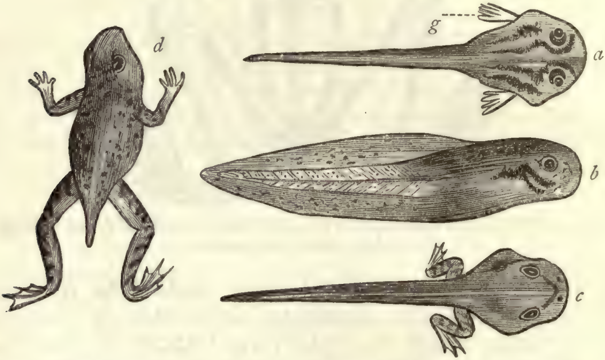

Fig. 283.—Development of the common Frog (*Rana temporaria*). *a* Tadpole viewed from above, showing the external branchiæ (*g*); *b* Side view of a somewhat older specimen, showing the fish-like tail; *c* Older specimen, in which the hind-legs have appeared; *d* Specimen in which all the limbs are present, but the tail has not been wholly absorbed. (After Bell.)

is the case with the *Urodela.* Even after the first appearance of the limbs, the tail is still retained as an instrument of progression; but as the limbs become fully developed, the tail is gradually absorbed (fig. 283, *d*), until in the adult it has wholly disappeared.

The development of the Frog is thus a good illustration of the general zoological law that the transient embryonic stages of the higher members of any division of the animal kingdom are often represented by the permanent condition of the lower members of the same division. Thus the transitory condition of the young Frog in its earliest stage, when the branchiæ are external, is permanently represented by the adult perennibranchiate *Urodela*, such as the Proteus or the Siren. The final stage, again, when the gills have disappeared and the limbs have been developed, but the tail has not been wholly absorbed, is represented by the caducibranchiate *Urodela*, such as the common Newt. In some of the Tree-frogs, however, there appears to be no true metamorphosis. Thus in the larvæ of *Hylodes* the branchiæ are absent or evanescent, the anterior and posterior limbs are developed contemporaneously, and the tail is absorbed within the first day after emergence from the egg.

The order *Anoura* comprises a considerable number of forms, but may be divided into the three principal sections of the *Pipidæ*, *Bufonidæ*, and *Ranidæ.* In the *Pipidæ*, or Surinam Toads, there are rarely teeth, and the mouth is destitute of a tongue. A singular and hideous species (*Pipa Americana*) is the best known, and it inhabits Brazil and Surinam. In this curious Amphibian the eggs are placed by the male on the back of the female, in the soft integument of which, in cell-like cavities, the eggs are hatched and the young developed. The larvæ possess external branchiæ, which are very early absorbed. In the aberrant form *Dactylethra*, the upper jaw is furnished with small teeth, and the three inner toes of the hind-feet are furnished with nails, as is the case with no other Amphibian, except *Salamandra unguiculata* amongst the *Urodela.* This curious form is found at the Cape of Good Hope and in Mozambique, and its larvæ appear to be destitute of external branchiæ.

In the Toads, or *Bufonidæ*, a tongue is present, but the jaws are not armed with teeth. The tongue agrees with that of the Frogs in being fixed to the *front* of the mouth, whilst it is *free behind*, so that it can be protruded for some distance from the mouth. In one Toad only (*Rhinophrynus*) is there a tongue which is free in front. The hind-limbs are not disproportionately developed, whilst the toes are only imperfectly webbed, and the toes of the fore-limb are free. The skin is warty and glandular. The common Toad (*Bufo vulgaris*) is an excellent example of this family. The Natter-jack Toad is the only other British species, but about fifty other forms are known, of which many are American.

In the *Ranidæ* the tongue has the same form as in the Toads, but the upper jaw always carries teeth. The hind-limbs are much larger than the fore-limbs, and are fitted for leaping, whilst the toes are webbed. The toes of the fore-limbs are free. The common Frog (*Rana temporaria*) is a good example of the typical *Ranidæ*. This familiar species (fig. 284) is found over nearly the whole of Europe, North Africa, Northern Asia, and North America. It hibernates, passing its winter sleep buried in mud at the bottom of ponds. Larger than the common Frog is the Eatable Frog (*Rana esculenta*) of Europe, and larger again than this is the Bull-frog (*Rana pipiens*) of North America. The Tree-frogs (*Hylidæ*) are adapted for a wholly different mode of life, having the toes of all the feet furnished with terminal suckers (fig. 276), by the help of which they climb with ease. They are mostly found in warm countries, especially in America, but one species (*Hyla arborea*) is European.

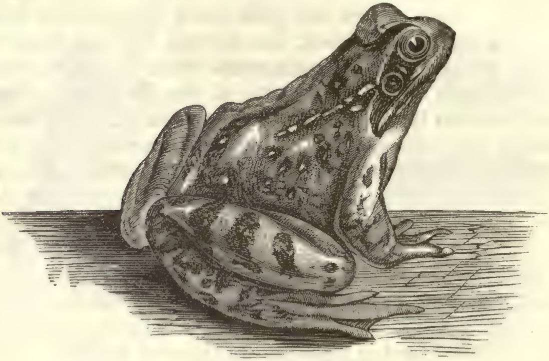

Fig. 284.—The common Frog (*Rana temporaria*).

In the curious American Tree-frogs forming the genus *Opisthodelphys*, the females have a dorsal brood-pouch, which extends over the back and opens posteriorly, and into which the eggs are introduced prior to hatching.

ORDER IV. LABYRINTHODONTIA.—The members of this, the last order of the Amphibia, are entirely extinct. They were Batrachians, probably most nearly allied to the *Urodela*, but all of large size, and some of gigantic dimensions, the skull of one species (*Labyrinthodon Jægeri*) being upwards of three feet in length and two feet in breadth. The Labyrinthodonts were first known to science simply by their footprints, which were found in certain sandstones of the age of the Trias. These footprints consisted of a series of alternate pairs of hand-shaped impressions, the hinder print of each pair being much larger than the one in front (fig. 285). So like were these impressions to the shape of the human hand, that the unknown animal which produced them was at once christened *Cheirotherium*, or "Hand-beast." Further discoveries, however soon showed that the footprints of *Cheirotherium* had been produced by different species of Batrachians, to which the name of Labyrinthodonts was applied, in consequence of the complex microscopic structure of the teeth.

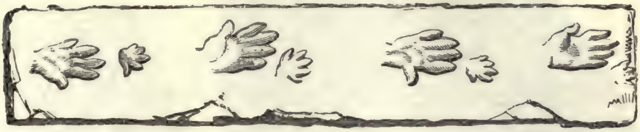

Fig. 285.—Footprints of a Labyrinthodont (*Cheirotherium*).

The Labyrinthodonts were "salamandriform, with relatively weak limbs and a long tail" (Huxley). The vertebral centra and arches were ossified, and the bodies of the dorsal vertebræ are biconcave (amphicœlous). "In the thoracic region three superficially sculptured exoskeletal plates, one median and two lateral, occupy the place of the interclavicle and clavicles, Between these and the pelvis is a peculiar armour, formed of rows of oval dermal plates, which lie on each side of the middle line of the abdomen, and are directed obliquely forwards and inwards to meet in that line" (Huxley).

The head was defended by an external covering or helmet of hard and polished osseous plates, sculptured on their external surface, and often exhibiting peculiar, smooth, symmetrical grooves—the so-called "mucous canals." The skull (fig. 287) was articulated to the vertebral column by two occipital condyles. The teeth (fig. 286) are rendered complex by numerous foldings of their parietes, giving rise to the "labyrinthine" pattern, from which the name of the order is derived.

There appear usually to have been both pairs of limbs developed, but some forms which have been referred here (such as *Ophiderpeton*) possessed a serpentiform body, and seem to have been apodal. Little is known, necessarily, of their development, but the singular genus *Archegosaurus* possessed permanent branchial arches, and was, therefore, apparently perennibranchiate (if not truly a larval form), whilst its notochord was persistent, and simply had rings of osseous matter deposited in it.

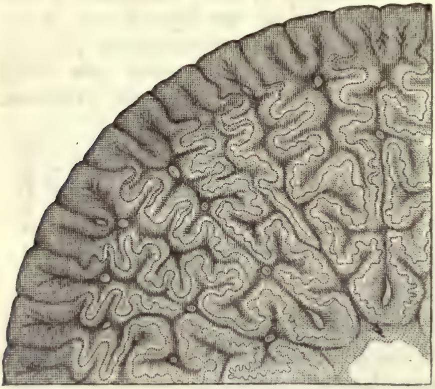

Fig. 286.—Section of the tooth of *Labyrinthodon* (*Mastodonsaurus*) *Jægeri*, showing the microscopic structure. Greatly enlarged. Trias.

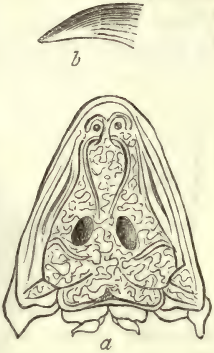

Fig. 287.—*a* Skull of *Labyrinthodon Jægeri*, much reduced in size; *b* Tooth of the same. Trias. Würtemberg.

As to their distribution in time, the Labyrinthodonts range from the Carboniferous to the Trias, inclusive, being most numerous in the former period, but attaining their maximum in point of size in the latter.

Distribution of Amphibia in Time.—From a geological point of view, by far the most important of the *Amphibia* are the *Labyrinthodontia*, the distribution of which has just been spoken of. The living orders of *Amphibia* are of much more modern date, being, with the exception of some not wholly certain Urodelans, wholly Tertiary and Post-tertiary. The *Anoura* are represented by both Toads and Frogs in Miocene times, and they have survived to the present day. The "Tailed" Amphibians are best known to geologists by a singular fossil, which was described by its original discoverer as human, under the name of *Homo diluvii testis.* The fossil in question is of Miocene age, and it is now known to belong to a Salamander, nearly allied to the Giant-salamander of Java (*Cryptobranchus*).

Geinitz has given the name of *Palæosiren* to a fossil Amphibian from the Permian, which he believes to be referable to the *Urodela.* Gaudry, under the title of *Salamandrella*, has also described certain tailed Amphibians from the Permian, which he believes to be true Salamandroids and not Labyrinthodonts. The same palæontologist also suggests that the Carboniferous genera *Raniceps* and *Apateon*, instead of being Labyrinthodonts, are really referable to the *Urodela.* Lastly, no remains of Cæcilians have as yet been detected in a fossil condition.

LITERATURE.

[In addition to many of the systematic works enumerated in the list of treatises relating to the Vertebrata generally (p. 459), the student may consult the following as to the living and extinct Amphibians:—]

1. Article "Amphibia." Huxley. 'Encyclopædia Britannica.' 9th ed. 1875.
2. Article "Amphibia." Bell. Todd's 'Cyclopædia of Anatomy and Physiology.' 1835-36.
3. "Catalogue of the Batrachia salientia in the Collections of the British Museum." Günther. 1858.
4. "History of British Reptiles." Bell.
5. "The Common Frog." St George Mivart. 1874.
6. "Systema Reptilium." Fitzinger. 1843.
7. "Lehrbuch der Zootomie." Von Siebold and Stannius.
8. "Erpétologie générale, ou histoire naturelle complète des Reptiles." Dumeril and Bibron. 1836.
9. "Classification of the Anourous Batrachians." St George Mivart. 'Proc. Zool. Soc.' 1869.
10. "Handbuch der Amphibien." Stannius.
11. "Beiträge zur Anatomie der Amphibien." J. Müller. 'Zeitschr. für Physiologie." 1832.
12. "Recherches sur l'osteologie et la myologie des Batraciens." Dugès. 1834.
13. "Zur Anatomie der Amphibien." Mayer. 1835.
14. "Observations in Myology." Humphry. 1872.
15. "Vergleichende Entwickelungsgeschichte des Kopfes der nackten Amphibien." Reichert. 1838.
16. "Histoire naturelle, développment, et metamorphose de la Salamandre terrestre." Rusconi and Configliachi. 1854.
17. "Report on the Labyrinthodonts of the Coal-Measures." Miall. 'Brit. Assoc. Reports.' 1873.
18. "Synopsis of Extinct Batrachia and Reptilia of North America." Cope.
19. "Synopsis of Extinct Batrachia from the Coal-Measures." Cope. 'Palæontology of Ohio,' vol. ii. 1875.
20. "Die Labyrinthodonten aus dem Bunten Sandstein." Burmeister. 1849.

DIVISION II.—SAUROPSIDA.

CHAPTER LIX.

CLASS III.—REPTILIA.

THE second great division of the Vertebrate sub-kingdom, according to Huxley, is that of the *Sauropsida*, comprising the true Reptiles and the Birds. It is, no doubt, at first sight an almost incredible thing that there should be any near bond of relationship between the Birds and the Reptiles, no two classes of animals being more unlike one another in habits and external appearance. It is, nevertheless, the fact that the Birds are more nearly related to the Reptiles than to any other class of the *Vertebrata*, and it will shortly be seen that many affinities and even transitional forms are known to exist between these great sections. The Reptiles and Birds, then, may be naturally included in a single primary section of Vertebrates, which may be called *Sauropsida* after Huxley, and which is defined by the possession of the following characters:—At no period of existence are branchiæ, or water-breathing respiratory organs, developed upon the visceral arches; the embryo is furnished with a well-developed amnion and allantois; the red corpuscles of the blood are nucleated (fig. 245, *b*, *c*); the skull articulates with the vertebral column by means of a single articulating surface or condyle; and each half or "ramus" of the lower jaw is composed of several pieces, and articulates with the skull, not directly, but by the intervention of a peculiar bone, called the "quadrate bone," or "os quadratum" (fig. 288).

These being the common characters of Reptiles and Birds, by which they are collectively distinguished from other Vertebrates, it remains to inquire what are the characters by which they are distinguished from one another. The following, then, are the characters which separate the Reptiles from the Birds:—The blood in Reptiles is cold—that is to say, slightly warmer than the external medium—owing mainly to the fact that the pulmonary and systemic circulations are always directly connected together, either within the heart or in its immediate neighbourhood, so that the body is supplied with a mixture of venous and arterial blood, in place of pure arterial blood alone. The terminations of the bronchi at the surface of the lung are closed, and do not communicate with air-sacs, placed in different parts of the body. When the epidermis develops horny structures, these are in the form of horny plates or scales, and never in the form of feathers. The fore-limbs are formed for various purposes, including in some cases even flight, but they are never constructed upon the type of the "wing" of Birds. Lastly, with one or two doubtful exceptions, whilst the ankle-joint is placed between the distal and proximal portions of the tarsus, the tarsal and metatarsal bones of the hind-limb are never anchylosed into a single bone.

These are the leading characters by which Reptiles are distinguished from Birds, but we must not forget the other distinctive peculiarities in which Reptiles agree with Birds, and differ from other Vertebrates — namely, the presence of an amnion and allantois in the embryo, the absence of branchiæ at all times of life, the possession of only one occipital condyle, and the articulation of the complex lower jaw with the skull by means of a quadrate bone.

It is now necessary to consider these characteristics of the *Reptilia* a little more minutely. The class includes the Tortoises and Turtles, the Snakes, the Lizards, the Crocodiles, and a number of extinct forms; and, with the exception of the Tortoises and Turtles, they are mostly of an elongated cylindrical shape, provided posteriorly with a long tail. The limbs may be altogether absent, as in the Snakes, or quite rudimentary, as in some of the Lizards; but, as a general rule, both pairs of limbs are present, sometimes in the form of ambulatory legs, sometimes as swimming-paddles, and in some extinct forms modified to subserve an aerial life. The endoskeleton is always well ossified, and is never cartilaginous or semi-cartilaginous, as in many fishes and some Amphibians. The skull articulates with the atlas by a single condyle. The lower jaw is complex, each half or ramus being composed of from four to six pieces, united to one another by sutures (fig. 288). In the Tortoises, however, these are anchylosed into a single piece, and the two rami are also anchylosed. In most reptiles, however, the two rami of the lower jaw are only loosely united—in the Snakes by ligaments and muscles only, in the Lizards by fibro-cartilage, and in the *Crocodilia* by a regular suture. In all, the lower jaw articulates with the skull by a quadrate bone (fig. 288, *a*); and as this often projects backwards, the opening of the mouth is often very extensive, and may even extend beyond the base of the skull. Teeth are usually present, but are not sunk in separate sockets or alveoli, except in the Crocodiles, and in some extinct forms. In the Tortoises and Turtles alone of living types there are no teeth, and the jaws are simply sheathed in horn, constituting a kind of beak like that of a bird.

As regards the exoskeleton, most Reptiles have horny epidermic scales, and they are divided into two great sections—called respectively *Squamata* and *Loricata*—according as the integumentary skeleton consists simply of these scales, or there are osseous plates developed in the derma as well. In the Tortoises, the epidermic plates unite with the bony exoskeleton and with the true endoskeleton to form the case or box in which the body of these animals is enclosed.

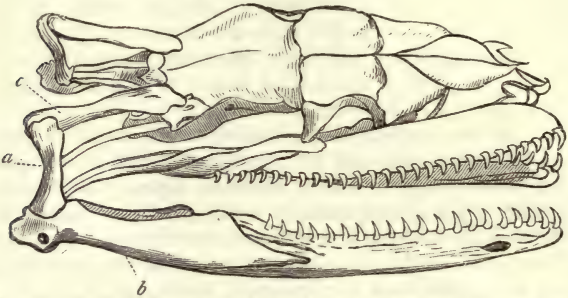

Fig. 288.—Skull of a Serpent (*Python*). *b* Articular portion of the lower jaw; *a* Quadrate bone; *c* Squamosal portion of the temporal bone.

The digestive system of the *Reptilia* possesses few characters of any special importance, except that the rectum opens, as in *Amphibia*, into a common cavity or "cloaca," which not only receives the fæces, but also serves for the discharge of the products of the urinary and generative organs.

The *heart* in the Reptiles consists of two completely separate auricles, and a ventricular cavity, which is divided into two by an incomplete partition. In the *Crocodilia* alone is the septum between the ventricles a perfect one; and even in these, as in all other Reptiles, the heart consists *functionally* of no more than three chambers. The ordinary course of the circulation, where the ventricular septum is imperfect, is as follows:—The impure venous blood returned from the body is, of course, poured by the venæ cavæ into the right auricle (fig. 289, *a*), and thence into the ventricle. The pure arterialised and aerated blood that has passed through the lungs, is, equally of course, poured into the left auricle (a'), and thence propelled into the ventricle (v). As the ventricular cavity is single, and not divided by a complete partition, it follows of necessity that there is a mixture in the ventricle, resulting in the production of a mixed fluid, consisting partly of venous and partly of arterial blood. This mixed fluid, then, occupies the common ventricular cavity, and by this it is driven both to the lungs (through the pulmonary artery), and to the body (through the systemic aorta). Consequently, in Reptiles, both the lungs and the various tissues and organs of the body are supplied with a mixture of arterial and venous blood, and not with unmixed blood—the lungs with purely venous, and the body with purely arterial blood—as is the case with the higher *Vertebrata*. In the *Crocodilia*, as before said, the partition between the ventricles is a complete one, and consequently this mixture of the arterial and venous blood cannot take place within the heart itself. In these Reptiles, however, a direct communication exists between the pulmonary artery and aorta (the right and left aortæ) by the so-called "foramen Panizzæ," close to the point where these vessels spring respectively from the right and left ventricle. In these Reptiles, therefore, the same mixture of arterial blood with venous takes place as in the lower *Reptilia*, though probably not to so complete an extent. It is this peculiarity of the circulation in all Reptiles which conditions their low temperature, slow respiration, and generally sluggish vital actions.

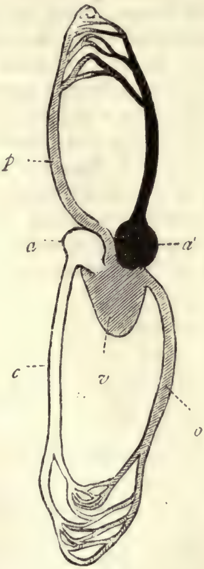

Fig. 289.—Diagram of the circulation in Reptiles. (The venous system is left light, the arterial system is black, and the vessels containing mixed blood are cross-shaded.) *a* Right auricle, receiving venous blood from the body; *a'* Left auricle, receiving arterial blood from the lungs; *v* Arterio-venous ventricle, containing mixed blood, which is driven by (*p*) the pulmonary artery to the lungs, and by (*o*) the aorta to the body.

The *lungs* in all Reptiles, except the Crocodiles, are less completely cellular than in the Birds and Mammals, and they often attain a very great size. In no Reptile is the cavity of the thorax shut off from that of the abdomen by a complete muscular partition or "diaphragm;" though traces of this structure are found in the Crocodiles. The lungs, therefore, often extend along the whole length of the thoracico-abdominal cavity. In no case are the lungs connected with air-receptacles situated in different parts of the body; and not uncommonly there is only a single active lung, the other being rudimentary or completely atrophied (*Ophidia*).

Lastly, all Reptiles are essentially oviparous, but in some cases the eggs are retained within the body till the young are ready to be excluded, and the animals are then ovo-viviparous. The egg-shell is usually parchment-like, but sometimes contains more or less calcareous matter.

CHAPTER LX.

DIVISIONS OF REPTILES.

CHELONIA AND OPHIDIA.

THE class *Reptilia* is divided into the following ten orders, of which the first four are represented by living forms, whilst the remaining six are extinct:—

1. *Chelonia* (Tortoises and Turtles).	Recent.
2. *Ophidia* (Snakes).	
3. *Lacertilia* (Lizards).	
4. *Crocodilia* (Crocodiles and Alligators).	
5. *Ichthyopterygia.*	Extinct.
6. *Sauropterygia.*	
7. *Anomodontia.*	
8. *Pterosauria.*	
9. *Deinosauria.*	
10. *Theriodontia.*	

ORDER I. CHELONIA.—The first order of living Reptiles is that of the *Chelonia*, comprising the Tortoises and Turtles, and distinguished by the following characters:—*There is an osseous exoskeleton which is combined with the endoskeleton to form a kind of bony case or box in which the body of the animal is enclosed, and which is covered by a leathery skin, or, more usually, by horny epidermic plates. The dorsal vertebræ, with* *the exception of the first, are immovably connected together, and are devoid of transverse processes. The ribs are greatly expanded* (fig. 290, *r*), *and are united to one another by sutures, so that the walls of the thoracic cavity are immovable. All the bones of the skull except the lower jaw and the hyoid bone are immovably united together. There are no teeth, and the jaws are encased in horn so as to form a kind of beak. The tongue is thick and fleshy. The heart is three-chambered, the ventricular septum being imperfect.* There is a large urinary bladder, and the anal aperture is longitudinal or circular. The lungs are voluminous, and respiration is by swallowing air, as in the Frogs. All will pass prolonged periods without food, and will live and move, even for months, after the removal of the entire brain (Redi).

Of these characters of the *Chelonia*, the most important and distinctive are the nature of the jaws, and the structure of the exoskeleton and skeleton. As regards the first of these points, the lower jaw in the adult appears to consist of a single piece, its complex character being masked by anchylosis. The separate pieces which really compose each ramus of the jaw are immovably anchylosed together, and the two rami are also united in front by a true bony union. There are also no teeth, and the edges of the jaws are simply sheathed in horn, constituting a sharp beak. In the *Chelydidæ* and *Trionycidæ*, however, the horny jaws are covered with soft skin, constituting a kind of lips. As regards the second of these points, the bony case (fig. 290) in which the body of a Chelonian is enclosed consists essentially of two pieces, a superior or dorsal piece, generally convex, called the "carapace," and an inferior or ventral piece, generally flat or concave, called the "plastron." The carapace and plastron are firmly united along their edges, but are so excavated in front and behind as to leave apertures for the head, tail, and fore and hind limbs. The limbs and tail can almost always be withdrawn at will under the shelter of the thoracico-abdominal case formed in this way by the carapace and plastron, and the head is also generally retractile.

The carapace or dorsal shield (fig. 291) is composed of the following elements:—

1. *The spinous processes of the dorsal vertebræ*, which are much flattened out laterally and form a series of broad plates, which are eight in number, and are termed the "neural plates" (*n*). 2. The ribs (*r r*) are united with broad and flattened plates of bone (*c′ c′*), which are connected with one another by lateral sutures, and are known as the "costal plates." In some cases, however, the costal plates, instead of being united

by the whole of their lateral margins, leave marginal apertures towards their extremities, and these openings are simply covered by a leathery skin or by horny plates. 3. The margin of the carapace is completed by a series of bony plates, which

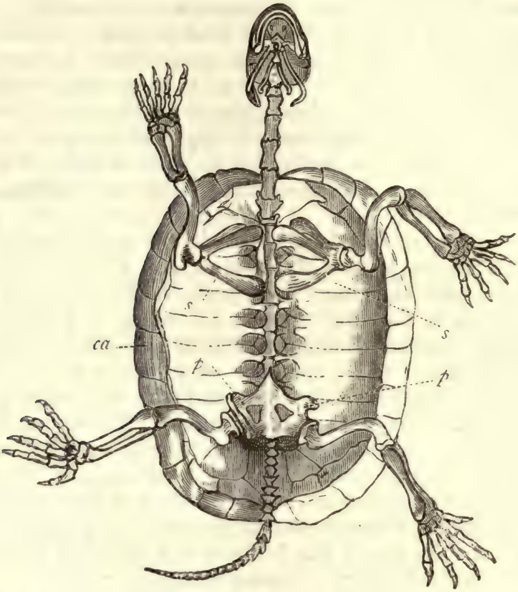

Fig. 290.—Skeleton of Tortoise (*Emys Europæa*), the plastron being removed. *ca* Carapace ; *r* Ribs, greatly expanded, and united by their edges ; *s* Scapular arch, placed within the carapace, and carrying the fore-limbs ; *p* Pelvic arch, also placed within the carapace, and carrying the hind-limbs.

are called the "marginal plates" (fig. 291, *m m*). These are variously regarded as being dermal bones belonging to the exoskeleton, or as being endoskeletal, and as representing the ossified cartilages of the ribs (in this last case the marginal plates would correspond with the "sternal ribs" of Birds). Of these marginal plates the one in the middle line of the carapace in front is known as the "nuchal" plate, and is larger than the rest, while the corresponding plate behind is termed the "pygal" plate (see fig. 293, *nu* and *py*).

The "plastron" or ventral shield (fig. 292) is composed of nine bony pieces, of which eight are in pairs, and the ninth is odd. Of the paired pieces, the anterior are the *episternals*, the middle pairs are the *hyosternals* and *hyposternals*, and the hinder pair are the *xiphisternals;* while the unpaired piece is termed the *entosternal* (fig. 292 *s*). The precise nature of the bones of the plastron is still a matter of doubt. Some regard them as wholly corresponding with the sternum or breast-bone; others regard them as wholly integumentary; while others, again, hold—what is doubtless the correct opinion—that the plastron is formed partly of bones belonging to the endoskeleton proper and representing the sternum, in part at any rate, and partly of integumentary ossifications.

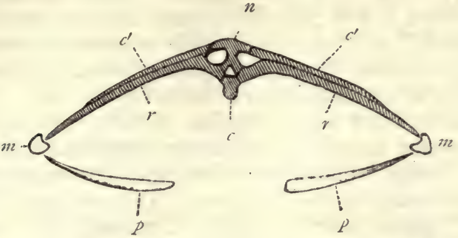

Fig. 291.—Transverse section of the skeleton of *Chelone midas* in the dorsal region. *c* Body of one of the dorsal vertebræ; *n* Expanded spinous process or "neural plate" of the same; *r r* Ribs; *c′ c′* "Costal plates;" *m m* Marginal plates; *p p* Lateral elements of the plastron. (After Huxley.)

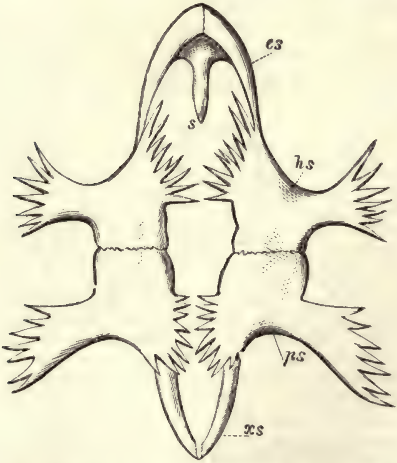

Fig. 292.—Bones of the plastron of the Loggerhead Turtle (*Chelone caouanna*). *s* Entosternal; *es* Episternal; *hs* Hyosternal; *ps* Hyposternal; *xs* Xiphisternal. (After Owen.)

Both the carapace and plastron are covered by a series of horny plates (rarely wanting), which are developed in the epidermis, and which are perfectly distinct from the bones which they cover. As encasing the upper surface of the carapace, these plates (which in some species constitute the "tortoise-shell" of commerce) have a general arrangement conforming with that of the bony plates beneath, though there is no numerical correspondence between the two. Thus the carapace, as we have seen, consists of (1) a median series of "neural" plates developed from the vertebræ; (2) a lateral series of "costal" plates on each side, corresponding with and largely formed by the ribs; and (3) a peripheral series of "marginal" plates (see fig. 293). Similarly, the epidermic plates (fig. 293) are arranged in (1) a median, "vertebral," or "neural" series; (2) a lateral series on each side, of "costal"

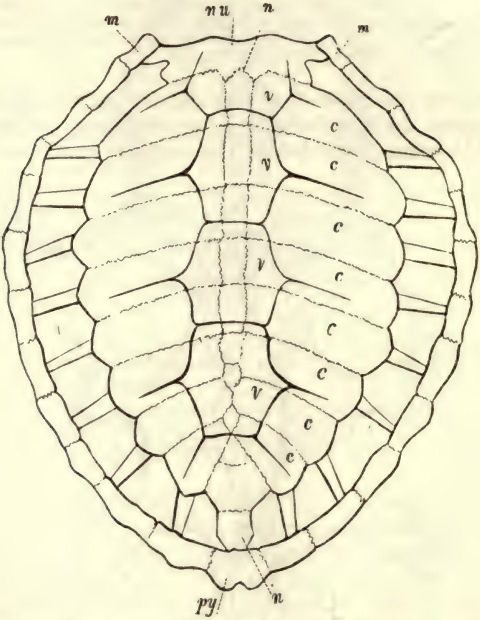

Fig. 293.—Carapace of the Loggerhead Turtle (*Chelone caouanna*), viewed from above (after Owen). In this form, the ribs are separate and free towards their extremities, and the osseous portions of the carapace are indicated by the light lines, while the epidermic plates are marked out by dark lines. *n n* The first and last of the median series of "neural plates;" *c c* The expanded ribs or "costal plates;" *m m* The first "marginal plate" on each side; *nu* Nuchal plate; *py* Pygal plate; *v v* Median series of epidermal plates, or "vertebral scutes."

scutes; and (3) a series of "marginal" scutes. The "vertebral" scutes, however, are only *five* in number; and each series of "costal" scutes consists only of *four* pieces, so that the number of epidermic plates is much smaller than that of the bony plates beneath. The "marginal" scutes, on the other hand, correspond in number with the "marginal plates" beneath them. They are, therefore, twenty-four or twenty-six in number, the anterior scute in the middle line being distinguished by the epithet of "nuchal," while the corresponding scute behind is termed "pygal."

The other points of importance as regards the endoskeleton are these:—

Firstly, The dorsal vertebræ are immovably joined together and have no transverse processes, the heads of the ribs uniting directly with the bodies of the vertebræ.

Secondly, The scapular and pelvic arches, supporting the fore and hind limbs respectively (fig. 290, *s* and *p*), are placed *within* the carapace, so that the scapular arch is thus inside the ribs, instead of being outside, as it normally is. The scapular arch consists of the shoulder-blade or scapula, and two other bones, of which one corresponds with the acromion process of human anatomy, and the other to the coracoid process, or to the "coracoid bone," of the Birds. The clavicles, as is also the case with the *Crocodilia*, are absent; but the three anterior pieces of the plastron may represent an interclavicle and clavicles.

The order *Chelonia* is conveniently divided into three sections, according as the limbs are natatory, amphibious, or terrestrial. In the first of these, the limbs are converted into most efficient swimming-paddles, all the toes being united by a common covering of integument. In this section are the well-known Turtles (*Cheloniidæ*), all of which swim with great ease and power, but are comparatively helpless upon the land (fig. 294). The legs are of unequal length, and the carapace is much depressed and flattened. The best-known species are the "edible" or Green Turtle (*Chelone midas*), the Loggerhead Turtle (*Chelone caouanna*), the Hawk's-bill Turtle (*C. imbricata*), and the Leathery Turtle (*Sphargis coriacea*). The Green Turtle is largely imported into this country as a delicacy, and occurs abundantly in various parts of the Atlantic and Indian Oceans. The Hawk's-bill Turtle is of even greater commercial importance, as the horny epidermic plates of the carapace constitute the "tortoise-shell" so largely used for ornamental purposes. The Leathery Turtle is remarkable in having the carapace covered with a leathery skin in place of the horny plates which are found in other species.

In the second section of the *Chelonia*, in which the limbs are adapted for an amphibious life, are the Mud-turtles or soft Tortoises (*Trionycidæ*), and the Terrapins (*Emydidæ*). In the *Trionycidæ* the development of the carapace is imperfect, the ribs being expanded and united to one another only near their bases, and leaving apertures near their extremities. The entire carapace is covered by a smooth leathery skin, and the horny jaws are furnished with fleshy lips. All the *Trionycidæ* inhabit fresh water and are carnivorous in their habits. Good examples are found in the Soft-shelled Turtle (*Trionyx ferox*), and the large and fierce Snapping Turtle (*Chelydra serpentina*) of the United States; but other species are found in Egypt and the East Indies. The Terrapins (*Emys*) have a horny beak, and have the shield covered with epidermic plates. They are inhabitants of fresh water, and are most of them natives of America.

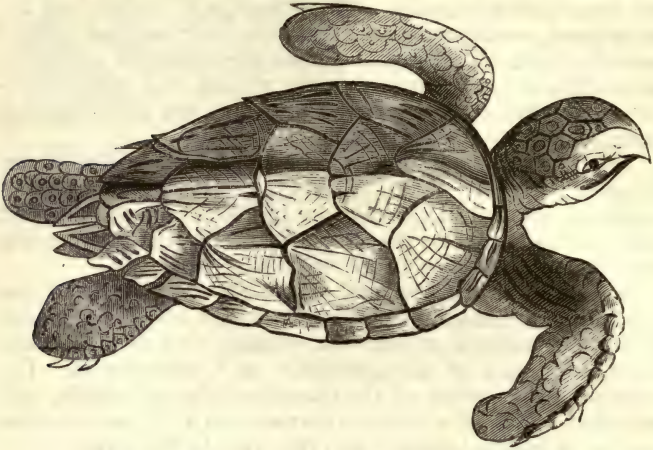

Fig. 294.—Hawk's-Bill Turtle (*Chelone imbricata*)—after Bell.

The third section of the *Chelonia* comprises only the Land Tortoises (*Testudinidæ*), in which the limbs are adapted for terrestrial progression, and the feet are furnished with short nails. The carapace is strongly convex, and is covered by horny epidermic plates; the head, limbs, and tail can be completely retracted within the carapace. Though capable of swimming, the Tortoises are really terrestrial animals, and are strictly vegetable feeders. The most familiar species is the *Testudo Græca*, which is indigenous in Spain, Italy, and Greece. A much larger species is the so-called Indian Tortoise (*Testudo Indica*), which inhabits the Seychelles and Galapagos Islands, and attains a length of over three feet.

DISTRIBUTION OF CHELONIA IN TIME.—The earliest-known traces of Chelonians occur in the Permian rocks, in the lower portion, that is, of the New Red Sandstone of older geologists. These traces, however, are not wholly satisfactory, since they consist solely of the footprints of the animal upon the ripple-marked surfaces of the sandstone. Of this nature is the *Chelichnus Duncani*, described by Sir William Jardine in his classical work on the 'Ichnology' of Annandale in Dumfriesshire. The earliest unequivocal remains of *Cheloniidæ* are in the Oolitic rocks (the *Chelone planiceps* of the Portland Stone).

Fossil *Cheloniidæ*, *Emydidæ*, and *Trionycidæ* occur, also, from the Upper Oolites to the present day, the Eocene period being peculiarly rich in their remains. In the Tertiary deposits of India (Siwalik Hills) there occurs a gigantic fossil Tortoise—the *Colossochelys Atlas*—which is believed to have been eighteen to twenty feet in length, and to have possibly survived to within the human period.

ORDER II. OPHIDIA.—The second order of Reptiles is that of the *Ophidia*, comprising the Snakes and Serpents, and distinguished by the following characters:—

The body is always more or less elongated, cylindrical, and worm-like, and whilst possessing a covering of horny scales, is always unprovided with a bony exoskeleton. The dorsal vertebræ are concave in front (*procœlous*), *with rudimentary transverse processes. There is never any sternum, nor pectoral arch, nor fore-limbs, nor sacrum, and as a rule there are no traces of hind-limbs.* Rudimentary hind-limbs, however, are occasionally present (*e.g.*, in *Python* and *Tortrix*). *There are always numerous ribs. The two halves or rami of the lower jaw are composed of several pieces, and the rami are united anteriorly by ligaments and muscles only, and not by cartilage or suture.* The lower jaw further articulates with the skull by means of a quadrate bone (fig. 288, *a*) which is always more or less movable, and is in turn united with the squamous portion of the temporal bone ("mastoid bone"), which is also movable, and is not firmly united with the skull. The superior maxillæ are united with the præmaxillæ by ligaments and muscles only, and the palatine arches are movable and armed with pointed recurved teeth. *Hooked conical teeth are always present, but they are never lodged in distinct sockets or alveoli.* Functionally they are capable of performing nothing more than merely holding the prey fast, and the Snakes are provided with no genuine masticatory apparatus. *The heart has three chambers, two auricles and a ventricle, the latter imperfectly divided into two cavities by an incomplete septum. The lungs and other paired organs are mostly not bilaterally symmetrical, one of each pair being either rudimentary or absent. There is no urinary bladder, and the cloacal aperture is transverse.*

Of these characters of the snakes, the most obvious and striking are to be found in the nature of the organs of locomotion. The front limbs, with the scapular arch and sternum, are invariably altogether absent; and the hind-limbs, if not wholly wanting, are never represented by more than an imperfectly-developed series of bones concealed within the muscles on each side of the anal aperture, and never exhibiting any outward evidence of their existence beyond the occasional presence of short horny claws or spurs ("calcaria"). In the entire absence, then, or rudimentary condition of the limbs, the Snakes progress by means of the ribs. These bones are always extremely numerous (sometimes amounting to more than three hundred pairs), and in the absence of a sternum, they are, of course, extremely movable. Their free extremities, in fact, are simply terminated by tapering cartilages, which are attached by muscular connections to the abdominal scales or "scuta" of the integument. By means of this arrangement the Serpents are enabled to progress rapidly, walking, so to speak, upon the ends of their ribs; their movements being much facilitated by the extreme mobility of the whole vertebral column, conditioned by the cup-and-ball articulation of the bodies of the vertebræ with one another.

The body in the Snakes is covered with numerous scales, developed in the dermis, and covered by a thin, translucent, superficial epidermic pellicle, which is periodically cast off and renewed. Usually the scales are flat and overlap one another; but sometimes they are tubercular and do not overlap. On the head and along the abdomen these scales are larger than over the rest of the body, and they constitute what are known as the "scuta" or shields.

The only other points in the anatomy of the *Ophidia* which demand special attention are the structure of the tongue, teeth, and eye.

The tongue in the Snakes is probably an organ more of touch than of taste. It consists of two muscular cylinders, united towards their bases, but free towards their extremities. The bifid organ, thus constituted, can be protruded and retracted at will, being in constant vibration when protruded, and being in great part concealed by a sheath when retracted.

As regards the eye of Serpents (fig. 296, A) the chief peculiarity lies in the manner in which it is protected externally. There are no eyelids, and hence the stony unwinking stare of all snakes. In place of eyelids, the eye is surrounded by a circle of scales (*e e*), to the circumference of which is attached a layer of transparent epidermis, which covers the whole eye (*d*), and is termed the antocular membrane. This is covered internally by a thin layer of the conjunctiva, which is reflected forwards from the conjunctiva covering the ball of the eye itself. In this way a cavity or chamber is formed between the two layers of conjunctiva, and the lachrymal secretion, by which the eye is moistened, is received into this. The outer epidermic layer (antocular membrane) covering the ball of the eye in front, is periodically shed with the rest of the epidermis, the animal being rendered thereby blind for a few days. The pupil of the eye is round in most Snakes, but forms a vertical slit in the venomous Serpents and in the Boas.

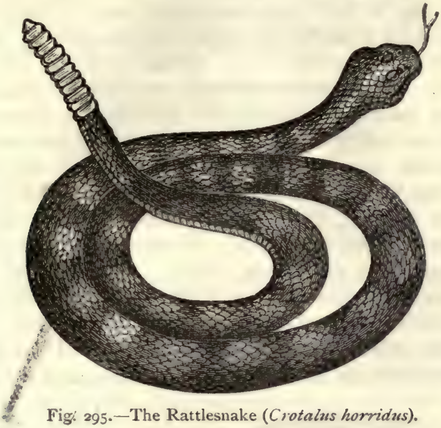

Fig. 295.—The Rattlesnake (*Crotalus horridus*).

As regards the dental and maxillary apparatus of the Serpents, the following points require notice: *Firstly*, in consequence of the articulation of the lower jaw with a movable quadrate bone, which is often directed backwards, in consequence of the quadrate bone being connected with a movable squamosal bone, and in consequence of the rami of the jaw being united in front by ligaments and muscles only,

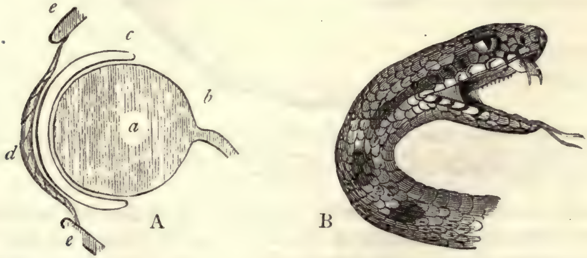

Fig. 296.—A, Diagram of the eye of a Serpent (after Cloquet): *a* Ball of the eye covered by a conjunctival sac, into which the lachrymal secretion is discharged; *b* Optic nerve; *d* Antocular membrane, formed by the epidermis; *e e* Ring of scales surrounding the eye. B, Head of the common Viper (*Pelias berus*)—after Bell—showing the bifid tongue, and the poison-fangs in the upper jaw.

the mouth in the Snakes is capable of opening to an enormous width, and the most astonishing feats in the way of swallowing can be performed. *Secondly*, this structure of the jaws accords exactly with the structure of the teeth, both concurring to render the Snakes wholly incapable of anything like mastication, and at the same time capable of swallowing immense morsels entire. The teeth, namely, are simply fitted for seizing and holding the prey, but not in any way for dividing or chewing it. In the non-venomous and most typical Snakes, the jaws and palatine bones carry continuous rows of solid conical teeth, so that there are four rows above and two below; and the superior maxillæ are very long and are not movable. *Thirdly*, in the Viperine Snakes, and the *Crotalidæ*, the ordinary teeth are wanting upon the superior maxillæ, whilst these bones are themselves very much shortened, and are capable of being raised and depressed at will. In place of the ordinary teeth, each maxilla carries a "poison-fang," in the form of a long, conical, curved fang, which is concealed in a fold of the mucous membrane when not in use, and has numerous germs or reserve-fangs behind it (figs. 296, B, and 297). Each tooth is perforated by a tube, opening by a distinct aperture at the apex of the tooth, and conveying the duct of the so-called poison-gland. (In reality the poison-duct of the fang is formed by an inflection of the tooth upon itself, and not by its actual perforation.) This is a gland (fig. 298), probably produced by a modification of one of the buccal salivary glands, situated behind and under the eye on each side, and secreting the fluid which renders the bite of these snakes dangerous or fatal. When the animal strikes its prey, the poison-fangs are erected by the elevation of the movable maxillæ (to which

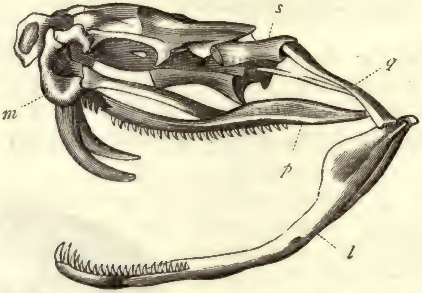

Fig. 297 – Skull of the Rattlesnake (after Dumeril and Bibron). *l* Left ramus of the lower jaw, united to the skull by the quadrate bone (*q*); *m* Upper jaw carrying the poison-fang; *p* Series of teeth upon the palate.

they are anchylosed), and the poison is forced through the tube which perforates each, partly by the contractions of the muscular walls of the gland, and partly by the muscles of the jaws. In most poisonous Snakes the superior maxillæ carry no other teeth except the poison-fangs and their rudimentary successors, but in some cases there are a few teeth behind the fangs; whilst the palatine teeth are always present, as in the harmless species. In some other venomous Snakes, again (*e.g.*, *Naja* and the *Hydrophidæ*), the jaws and teeth agree in most characters with those of the non-venomous Snakes, but the first maxillary teeth are larger than the others, and form canaliculated fangs. Lastly, in a few forms the terminal maxillary teeth are deeply canaliculated, but are not connected with the duct of any poison-gland.

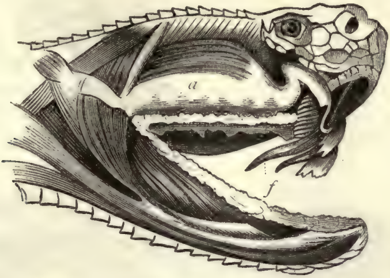

Fig 298.—The head of the Rattlesnake, dissected to show the poison-gland (*a*) and poison-fangs (*f*). (After Duvernoy.)

Fourthly, in all the Serpents the teeth are anchylosed with the jaw, and are never sunk into distinct sockets or alveoli.

The *Ophidia* are usually classified in accordance with the characters of their dental apparatus, and may be divided as follows, some minor groups being omitted: (1.) The *Viperina* comprise the most typical of the venomous Snakes (*Venenosa*), and include the common Vipers (*Viperidæ*) and the Rattlesnakes (*Crotalidæ*), the former being mostly confined to the Old World, whilst the latter are mainly American. The common Viper (*Pelias berus*) occurs abundantly in England and Scotland, and is capable of inflicting a severe and even dangerous bite, though it does not appear that fatal effects commonly follow except in the case of children or subjects previously debilitated. The true Rattlesnakes (*Crotalus*) are exclusively natives of America, and they are highly poisonous. The extremity of the tail in the true Rattlesnake (*Crotalus horridus*, fig. 295) is furnished with a series of horny epidermic cells of an undulated pyramidal shape, articulated one within the other, constituting an appendage which is known as the "rattle." Before striking its prey, the Rattlesnake throws itself into a coil, and shakes its rattle, as it does also when alarmed. According to Professor Shaler, the use of the rattle is to imitate the note of the Cicada, and thus to attract birds which prey upon this insect; but its function is more probably sexual. The Indian snakes belonging to the genus *Trimeresurus*, and some other less important forms, are also placed amongst the *Crotalidæ*. The head of the Viperine Snakes (figs. 296, 300) is broad, somewhat triangular in shape, broadest in its middle, and showing a very distinct line of demarcation between the head and neck. The head, also, is usually covered with small scales, rarely interspersed with larger plates or "scuta" (fig. 300). Other well-known members of this group are the Death-adder (*Acanthophis tortor*) of Australia, the Horned Viper (*Cerastes*) of Africa, and the Puff-adder (*Clotho arietans*) of the Cape of Good Hope.

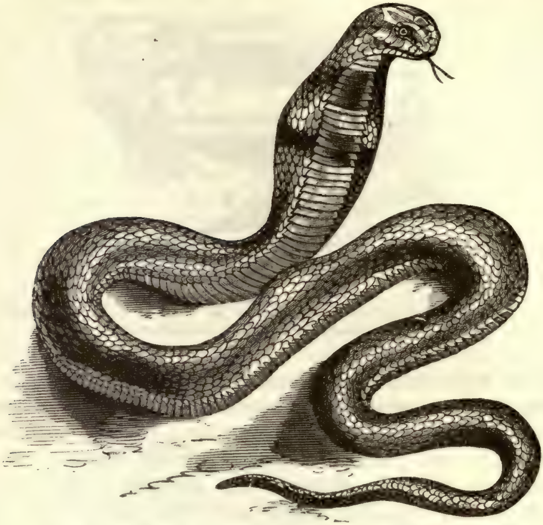

Fig. 299.—The *Naja Haje*, a venomous Colubrine Snake.

(2.) The *Elapina* are poisonous snakes, in which the poison-fangs are permanently fixed and erect, and have smaller solid teeth behind them. The head is shield-shaped, and not much wider than the body. This group comprises some of the most deadly of all the Serpents, one of the best known being the Hooded Snake or *Cobra di Capello* (*Naja tripudians*), which is commonly found in Hindostan, and is the snake usually carried about by the Indian snake-charmers. It varies from two to six feet in length, and the neck can be extensively dilated, covering the head like a hood. A nearly allied species is the *Naja Haje* (fig. 299) of Egypt. The genus *Bungarus*, including the deadly "Kerait" (*B. cæruleus*) of India, is nearly allied to *Naja*, but the neck is not dilatable. America has representatives of this family in the beautifully-marked Coral-snakes and Harlequin-snakes (*Elaps*), and the Australian region is also not without them (*Hoplocephalus*, &c.)

(3.) The *Hydrophidæ* comprise aquatic Ophidians which have the tail vertically compressed and broadened out. They are found principally in the Indian and Chinese seas, often frequenting the mouths of rivers, though sometimes ranging far from land. They are extremely poisonous, and swim with great ease and rapidity.

(4.) The *Colubrina* comprise an immense number of altogether innocuous snakes, in which the superior maxillæ are provided with solid teeth only, and there are no fangs. An excellent example of this group is the common Ringed Snake (*Coluber* or *Tropidonotus natrix*) of Britain, a perfectly harmless animal, which is commonly found in damp situations, and which lives mainly upon frogs. Closely allied to this is the Black Snake (*Bascanion constrictor*) of North America, which attains a length of from three to five feet, but is perfectly harmless, so far as man is concerned.

(5.) The *Pythonina* comprise the well-known serpents termed the Boas, Pythons, Anacondas, and Rock-snakes. The members of this group are the largest of all living snakes, attaining a length of certainly over twenty feet. Their bite is perfectly harmless, but they are nevertheless highly dangerous and destructive animals, owing to their great size and enormous muscular power. They seize their prey and coil themselves round it in numerous folds, by tightening which they gradually reduce their victim to the condition of a shapeless bolus, fit to be swallowed. In this way a good-sized Python or Boa will certainly dispose of an animal as large as a sheep or goat, and it is asserted that even human beings may be thus devoured by large individuals of the family. The Boas and Pythons occur in both the Old and New Worlds, the Pythons, however, all belonging to the Old World, and they are amongst the most formidable of all living Ophidians. They possess rudimentary hind-limbs terminating in horny anal spurs, which co-operate with the prehensile tail in enabling the animal to suspend itself from trees. In all, also, the dental apparatus is extremely powerful, giving a firm hold for the constriction of the prey.

(6.) The *Typhlopidæ* constitute an aberrant group of snakes, distinguished from the typical Ophidians by the comparative narrowness of their gape. They are found in both the Old and New Worlds, in warm latitudes, are possessed of quite rudimentary eyes, and burrow in the ground. Some of them are of very small size, and somewhat resemble earthworms. Nearly allied to the genus *Typhlops* itself is the Indian *Uropeltis*, which is also subterranean in its habits.

A good *general* character by means of which the poisonous Viperine Snakes may be distinguished from the harmless Colubrine forms is in the shape and armature of the head. In the *Viperina*, as before said, the head (figs. 296, 300) is triangular, broadest behind, and separated from the neck by a more or less marked diminution in the diameter of this latter part. The scales, too, which cover the head, are of small size. In the Colubrine Snakes, on the other hand, the head is not markedly triangular, and gradually tapers off into the neck, whilst the upper surface of the head is usually covered with large shield-like plates or "scuta" (fig. 300, A).

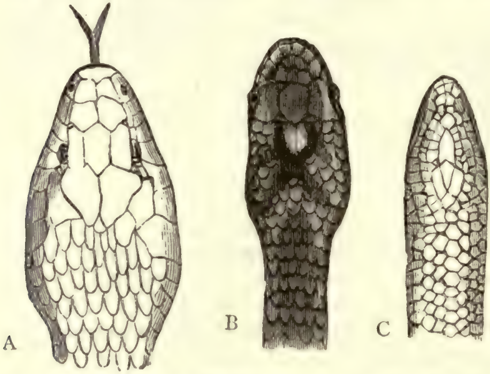

Fig. 300.—A, Head of Colubrine Snake (*Coluber natrix*); B, Head of Viperine Snake (*Pelias berus*); C, Head of Blind-worm (*Anguis fragilis*), one of the serpentiform Lizards. (After Bell).

Distribution of Ophidia in Time.—The *Ophidia* are not known to occur in any Palæozoic or Mesozoic deposit. The earliest-known traces of any serpent are in the Lower Kainozoic rocks, the oldest being the *Palæophis toliapicus* of the

London Clay of Sheppey. The nearly-allied *Palæophis typhæus* of the Eocene beds of Bracklesham appears to have been a Boa-constrictor-like snake of about twenty feet in length. Other species of *Palæophis* have been described from the Tertiary rocks of the United States, and the genus *Dinophis* has been formed for the reception of another gigantic constricting serpent from the same formation. In some of the later deposits have been found the poison-fangs of a venomous snake. Upon the whole, however, the Snakes must be looked upon as a comparatively modern group, and not as one of any great geological antiquity.

CHAPTER LXI.

LACERTILIA AND CROCODILIA.

ORDER III. LACERTILIA.—The third order of Reptiles is that of the *Lacertilia*, comprising all those animals which are commonly known as Lizards, together with some serpentiform animals, such as the Blind-worms. The *Lacertilia* are distinguished by the following characters :—

As a general rule, there are *two pairs of well-developed limbs, but there may be only one pair, or all the limbs may be absent. A scapular arch is always present, whatever the condition of the limbs may be. An exoskeleton, in the form of horny scales like those of the Snakes, is almost always present. The vertebræ of the dorsal region are procœlous or concave in front, rarely amphicœlous or concave at both ends.* There is a single transverse process at each side, and the heads of the ribs are simple and undivided. There is either no sacrum, or the sacral vertebræ rarely exceed two in number. *The teeth are not lodged in distinct sockets (some extinct forms constituting an exception to this statement). The eyes are generally furnished with movable eyelids. The heart consists of two auricles and a ventricle, the latter partially divided by an incomplete partition. There is a urinary bladder, and the aperture of the cloaca is transverse.*

As a general rule, the animals included under this order have four well-developed legs (fig. 301), and would therefore be popularly called "Lizards." In some (*Chirotes*) there are no hind-feet ; in some (*Bipes*) the fore-limbs are wanting ; and others (*Anguis*, *Pseudopus*, and *Amphisbæna*) are entirely destitute of limbs, thus coming closely to resemble the true Snakes or Ophidians in external appearance. These serpentiform Lizards, however, can be distinguished from the true Snakes, amongst other characters, more especially by the structure of

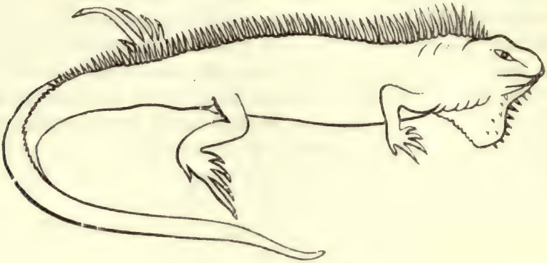

Fig. 301.—Iguana.

the jaws. In the Snakes, as before said, the two rami of the lower jaw are loosely united in front by ligaments and muscles, and are attached behind to a movable quadrate bone, which is in turn connected with a movable squamosal, this giving an enormous width of gape to these animals. In the Lizards, however, even in those most like the Snakes, the halves of the lower jaw are firmly united to one another in front; and though the quadrate bone is usually more or less movable, the jaws can in no case be separated to anything like the extent that characterises the *Ophidia.*

Another good general character is to be found in the structure of the protective coverings of the eye. In the Snakes, eyelids are wanting, and the eye is simply covered by a layer of epidermis, constituting the so-called "antocular membrane." In almost all the Lizards, on the other hand, including most of the completely snake-like forms, there are movable eyelids, and in few cases is there any structure comparable to the antocular membrane of the true Snakes. Lastly, the typical Lizards all possess a sternum or breast-bone, but this is wanting in some of the snake-like forms, so that it cannot be appealed to as a character by which the *Lacertilia* can be separated from the *Ophidia.* Whatever the condition of the limbs may be, there is, however, always a pectoral arch more or less completely developed, even though the pelvic arch should be wanting.

The whole order of the *Lacertilia* is very often united with the next group of the Crocodilia, under the name of *Sauria.* The term "Saurian," however, is an exceedingly convenient one to designate all the Reptiles which approach the typical

Lizards in external configuration, whatever their exact nature may be; and from this point of view it is often very useful as applied to many fossil forms, the structure of which is only imperfectly known. It is therefore perhaps best to employ this term merely in a loose general sense. All the Lacertilians possess teeth, though these vary considerably in their arrangement. (If the extinct *Rhynchosaurus* be truly Lacertilian, this genus has apparently no teeth.) The teeth are always simple, sometimes sharp and conical (Monitor), sometimes blade-like with serrated edges (Iguana), sometimes with rounded crushing crowns (*Cyclodus*). Usually the teeth become anchylosed to the jaw, when they may be fixed by their sides to the inner wall of the alveolar border of the jaw ("pleurodont" dentition), or may be attached by their bases to the summit of this border ("acrodont" dentition). In the extinct *Protorosauria*, the teeth are implanted in distinct sockets ("thecodont" dentition).

The *Lacertilia* are sometimes divided into three sections in accordance with the structure of the tongue. In one group, including the greater number of the members of the order, the tongue is long, protrusible, and forked (*Fissilinguia* or *Leptoglossa*), as in the Serpents. In a second group (*Brevilinguia* or *Pachyglossa*), including the Geckos and Agamids, the tongue is thick, fleshy, and not protrusible. Lastly, in a third group (*Vermilinguia*) are placed the Chameleons, with their long protrusible worm-like tongue, the extremity of which is clubbed. The following are the principal families of the Lacertilians.

The first family of importance is that of the *Amphisbænidæ*, including a number of serpentiform lizards, in which both pairs of limbs are uniformly absent (except in the Mexican *Chirotes*, in which the fore-limbs are present). All, however, possess a pectoral arch, and they are further distinguished from the Ophidians by the fact that the rami of the lower jaw are united by suture, so as greatly to restrict the gape. The type-genus, *Amphisbæna*, is South American, and comprises apodal snake-like lizards with short blunt tails, having the vent situated nearly at the end of the body.

In the family of the *Chalcididæ* we also have lizards with long snake-like bodies, but minute fore and hind limbs are present. The scales are rectangular, and are arranged in transverse bands which do not overlap. All the members of this group are American. In the nearly allied *Zonuridæ* the limbs may be well developed, rudimentary, or wholly wanting; there is a longitudinal fold of skin on each side of the body;

and the abdominal scales are square or roundish, and disposed in cross bands. The ears are distinct, and the eyes are provided with eyelids. In this group are the footless American Glass-snakes (*Ophisaurus*), and the Sheltopusiks (*Pseudopus*) of the Old World, in which the limbs are wanting, or a rudimentary pair of hind-legs is present.

More important than any of the preceding is the large and widely distributed family of the *Scincidæ*, comprising a number of small Lacertilians, some of which are completely snake-like, whilst others possess a single pair of limbs, and others again have the normal two pairs of limbs in a well-developed condition. All possess movable eyelids, and in all the conformation of the lower jaw is Lacertilian, and not Ophidian. All the Scincoidean Lizards have the body covered by similar scales overlapping one another like the scales of fishes, whilst the head is protected by larger symmetrical plates. The tongue is free, fleshy, and slightly notched.

Of the snake-like forms of this group, none is more familiarly known than the Blind-worm or Slow-worm (*Anguis fragilis*, fig. 302) which is found over almost the whole of Europe, in western Asia, and northern Africa, and which is one of the most abundant of the British Reptiles. The Blind-worm possesses no external appearance of limbs, though the scapular and pelvic arches are present in a rudimentary condition. Its appearance is completely serpentiform, and it is vulgarly regarded as a

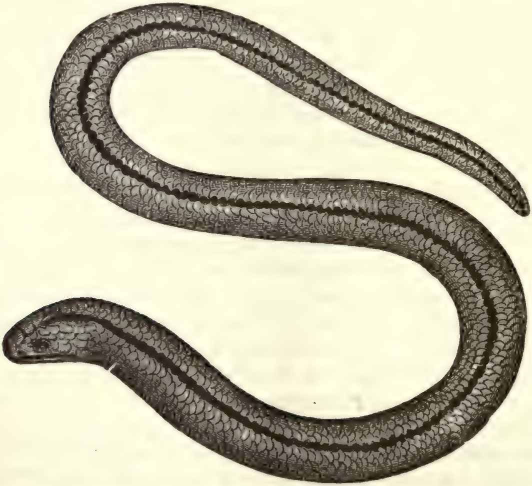

Fig. 302.—The Blind-worm (*Anguis fragilis*)—after Bell.

dangerous and venomous animal, but quite erroneously, as it is even unable to pierce the human skin. It is a perfectly harmless animal, living upon worms, insects, and snails, and hibernating during the winter. It derives its specific name of *fragilis* from the fact that when alarmed it stiffens its muscles to such an extent that the tail can be readily broken off, as if it were brittle.

Numerous other small Lizards are referable to the *Scincidæ*, but it is only necessary to mention the Skinks themselves (*Scincus*), in which both pairs of limbs are present in a well-developed state. The Skinks are found in almost all the warmer parts of the Old World, and closely-allied forms (such as the West Indian "Galliwasp") are found in the New World. The common Skink (fig. 303) is a native of Arabia and Africa. It attains a length of eight or nine inches, and was formerly used in various diseases as a remedy.

Passing over several small groups, the next family requiring consideration is that of the *Lacertidæ*, comprising the typical Lizards, in which there are always four well-developed limbs, each terminated by five free toes of unequal lengths. The body is covered with scales, which assume the form of shields or "scuta" over the abdomen and on the head, the scales of the former region being square and arranged in transverse bands. The tail is rounded. The tongue is slender, bifid, and protrusible, and the eyes have distinct lids. The only truly British Lizards are the Sand-lizard (*Lacerta agilis*) and the Viviparous Lizard (*Zootoca vivipara*); and the commonest form upon the Continent is the graceful little Green Lizard (*Lacerta viridis*), which also occurs in Jersey. The Lizards of

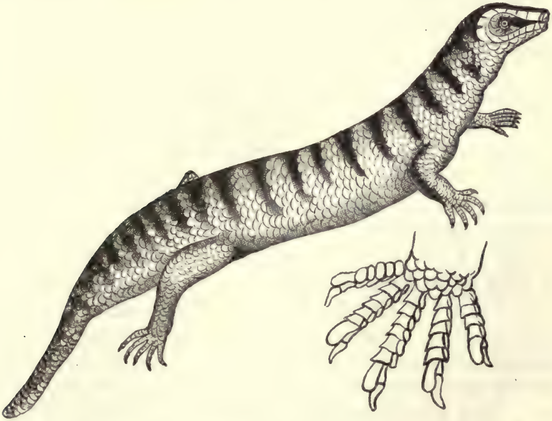

Fig. 303.—The common Skink (*Scincus officinalis*).

the Old World are represented in America by the *Ameivæ*, some of which attain a length of several feet.

Very closely allied to the true Lizards are the *Varanidæ* or Monitors which are indeed chiefly separated by the comparatively trivial fact that the abdomen and head are covered with small non-imbricating scales, and not with large "scuta." The tongue is protrusible and fleshy, like that of the Snakes. The teeth are lodged in a common alveolar groove, which has no internal border; and there are no palatal teeth. The tail has a double row of carinated scales, and is cylindrical in the terrestrial forms, and compressed in those whose habits are aquatic. The Monitors are exclusively found in the Old World (Asia, Africa, and Australia), and are the largest of all the recent *Lacertilia;* the *Varanus Niloticus* of Egypt attaining a length of six feet, and the *Hydrosaurus salvator* of the East Indian Archipelago attaining to as much as eight feet. The *Heloderma horridum* of Mexico is sometimes placed here.

The *Iguanidæ* constitute another large family of Lizards, belonging (if the *Agamidæ* be excluded) entirely to the New World. The tongue is thick, fleshy, notched at its extremity only, and not protrusible. Mostly there is a dorsal crest, and a goitre or throat-pouch. The body is covered with imbricated scales. They are often divided into "ground-iguanas," in which the body is flat and depressed, and "tree-iguanas," in which the body is compressed. The members of the genus *Iguana* itself (fig. 301) are confined to South America and the West Indies, and are distinguished by having the throat furnished with a pendulous dewlap or fold of skin, the edge of which is toothed. The back and tail, too, are furnished with an erect crest of pointed scales. The common Iguana (*I. tuberculata*) attains a length of from four to five feet, and though not of a very inviting appearance, is highly esteemed as food. The Basilisks (*Basiliscus*) have the top of the head furnished with a membranous sac, which can be distended with air at will.

The family of the *Agamidæ* is closely allied to that of the *Iguanidæ* proper, and represents it in the Old World. The body is covered with imbricated, generally rhombic, scales; the tongue is thick and non-protrusible; the eyes have eyelids; and the teeth are implanted on the edge of the bones of the jaws.

The Lizards of this group are distributed over nearly the whole of the Old World (principally Asia, Africa, and Australia), and are either arboreal or terrestrial in habit. Good examples are the *Stellio vulgaris* of the Levant, the *Agama muricata* of Australia, and the hideous *Moloch horridus* of the same country. Here also belongs the curious little Frill

Lizard (*Chlamydosaurus*) of Australia, which has the neck furnished on each side with a membranous plaited frill, which can be erected at will. More remarkable than the above are the little Flying Dragons (*Draco*) of the East Indies and Indian Archipelago. In these singular little Lizards there is a broad membranous expansion on each side, formed by a fold of the integument, supported upon the five or six posterior or false ribs, which run straight out from the spinal column (fig. 304). By means of these lateral expansions of the skin, the *Draco* can take long flying leaps from tree to tree, and can pursue the insects on which it feeds; but the lateral membranes simply act as parachutes, and there is no power of true flight, properly so called.

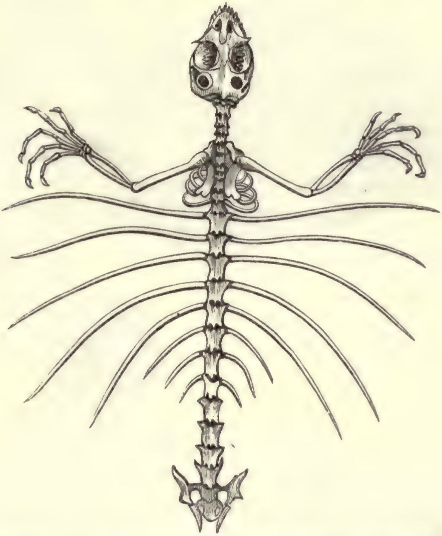

Fig. 304.—Fore-portion of the skeleton of *Draco volans*, the tail being omitted, showing the posterior or false ribs supporting the parachute.

The *Geckotidæ* form a large family of Lizards, comprising a great number of species, occurring in almost all parts of the world between and near the tropics. The tongue is wide, flat, scarcely notched at its free extremity, and hardly at all protrusible. The eyes are large, mostly with extremely short lids, the pupil mostly vertical and linear, but sometimes circular. The vertebræ are amphicœlous. The teeth are numerous, small, compressed, and implanted on the inner edge of the jaw. The nails (when present) are mostly hooked and retractile, and the toes are furnished below with imbricated plates or with adhesive discs. The animal is generally capable of running on the smoothest surfaces, or suspending itself back-downwards. They feed on insects, and are found in abundance in the warmer parts of both the Old and New Worlds.

Another remarkable family of Lacertilians is that of the *Chamæleontidæ*, containing, among other species, the familiar little *Chamæleo Africanus*, which occurs abundantly in the north of Africa and in Egypt, and is so well known for its power of changing its colour under irritation or excitement. In this genus the eye (fig. 306) is of large size, and is covered by a single circular lid, perforated centrally by a small aperture, by which the rays of light reach the pupil. The Chameleon

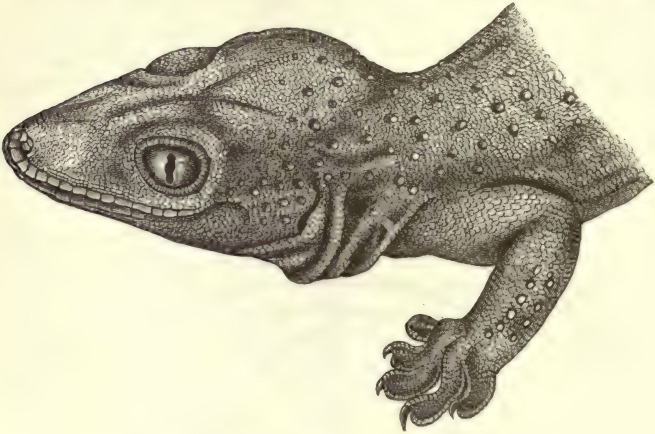

Fig. 305.—Head of *Gecko stentor*. (After Günther.)

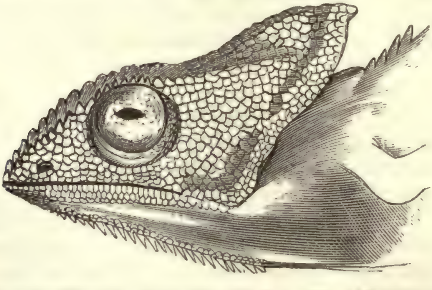

Fig. 306.—Head of a Chameleon (*C. Petersii*). (After Gray.)

is naturally a sluggish animal, but it catches its food, consisting of insects, by darting out its long, fleshy, and glutinous tongue—an operation which it effects with the most extraordinary rapidity.

The tail in the Chameleons is round and prehensile, the body compressed, and the skin like shagreen. The tongue is long, vermiform, club-shaped in front, and very extensile. The toes are adapted for the arboreal life and scansorial habits of the animal, being so arranged as to form two equal and opposable sets. The lungs are excessively voluminous. The Chameleons are exceedingly sluggish and slow in their movements, and are confined to the warmer parts of the Old World.

The last group of living Lizards which requires notice is that of the *Rhynchocephalia*, a group comprising only the curious genus *Hatteria* or *Sphenodon*, which is so aberrant in its characters that this section may well be regarded as a suborder of *Lacertilia*. Only one species (*H. punctata*) of this genus is known, and it inhabits New Zealand.

In this singular form (fig. 307) the vertebræ are amphicœlous, and some of the ribs bear "uncinate processes" similar to those of Birds. The quadrate bone is not movable, and is united by suture with the skull. The teeth are completely amalgamated by anchylosis with the jaws, and are developed in the mandible, præmaxillæ, maxillæ, and in a longitudinal series upon the palatine bones. The præmaxillary teeth are two in number, and are of large size and scalpriform in shape. The serrated edge of the mandible is received in the groove between the palatine teeth and the cutting edges of the maxillæ, the alveolar borders of which are hard and as highly polished as the teeth themselves, the function of which they discharge when the

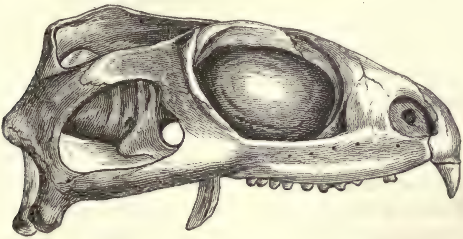

Fig. 307.—Side view of the skull of *Hatteria punctata*, the lower jaw being removed. (After Günther.)

latter are ground down in advanced age. Unlike any other Saurian, *Hatteria* is devoid of any copulatory organ.

Distribution of Lacertilia in Time.—It is hardly possible, with our present knowledge, to speak very positively as to the exact range of the *Lacertilia* in time. This uncertainty arises from two causes,—firstly, that there is some doubt as to the exact age of some deposits which have yielded Lacertilian remains; and secondly, that the affinities of some extinct Reptiles are a matter of considerable question. Upon the whole, the oldest known Lacertilian would appear to be the *Protorosaurus* of the Middle Permian rocks; though good authorities have placed this form in the Crocodilian group of the *Thecodontia*. *Protorosaurus* attained a length of between five or six feet, and differs from all existing Lizards in having its teeth implanted in distinct sockets—this being a Crocodilian character. In other respects, the Permian reptile approximates closely to the living Monitors (*Varanidæ*), and its slightly cupped vertebræ would lead to the belief that it was aquatic in its habits. Both pairs of limbs were present, both pentadactylous, and constructed on the type of the limbs of the typical Lizards.

In rocks known or supposed to be of Triassic age, several Lacertilian reptiles have been discovered, of which the most important are *Telerpeton*, *Hyperodapedon*, and *Rhynchosaurus*, of which the last is sometimes referred to the group of the *Anomodontia*, to be subsequently spoken of.

In the Jurassic period, the remains of Lacertilians are not unknown, but call for little special notice. Several forms of little importance have been described from the Middle Oolites. In the fresh-water strata of the Purbeck series (Upper Oolites), occur the remains which have been referred to the genera *Nuthetes*, *Macellodon*, *Saurillus*, and *Echinodon*. These are, perhaps, the first traces in the stratified series of remains, the affinities of which to the typical *Lacertidæ* cannot be disputed.

In the Cretaceous rocks occur the singular Lacertilians which form the group of the "Mosasauroids." These remarkable Reptiles were of gigantic size, *Mosasaurus princeps* being believed to have attained the enormous length of not less than seventy-five feet. The teeth of these reptiles are long, conical, and slightly curved; but they are anchylosed to the jaw, and are not sunk into distinct sockets as in the living Crocodiles. The vertebræ are procœlous. From the shortness of the humerus, and the indications that the vertebral column was unusually flexible, and that the tail was laterally compressed, it was early conjectured that the Mosasauroids were marine and aquatic in their habits. This conjecture has been raised to the rank of a certainty by the discovery that the fore and hind limbs of the Mosasauroids were in the form of fin-like paddles, resembling the flippers of whales in general structure, and in having the digits distinct and only conjoined by integument (fig. 308). There can therefore be no doubt that *Mosasaurus*—like the living *Amblyrhynchus*—was aquatic in its habits, and frequented the sea-shore, coming, in fact, only occasionally to the land. Professor Marsh has also recently shown that some species possess bony dermal scutes, thus rendering their Lacertilian affinities somewhat dubious.

Though possessing certain aberrant characters, it seems best in the meanwhile to regard the *Mosasauridæ* (= the *Pythonomorpha* of Cope) as an extinct group of the *Lacertilia*.

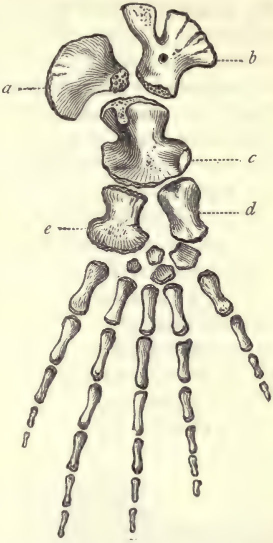

Fig. 308.—Right anterior paddle of *Lestosaurus simus*, one-twelfth of the natural size. (After Marsh.) *a* Scapula; *b* Coracoid; *c* Humerus; *d* Radius; *e* Ulna.

ORDER IV. CROCODILIA.—The last and highest order of the living *Reptilia* is that of the *Crocodilia*, including the living Crocodiles, Alligators, and Gavials, and characterised by the following peculiarities:—

The body is covered with an outer epidermic exoskeleton composed of horny scales, and an inner dermal exoskeleton consisting of transverse rows of squared bony plates or scutes, which may be confined to the dorsal surface alone, or may exist on the ventral surface as well, and which are disposed on the back of the neck into groups of different form and number in certain species. The bones of the skull and face are firmly united together, and the two halves or rami of the lower jaw are united in front by a suture. There is a single row of teeth, which are implanted in distinct sockets, and hollowed at the base for the germs of the new teeth, by which they are successively pushed out and replaced during the life of the animal. *The centra of the dorsal vertebræ in all living Crocodilia are procœlous or concave in front,* but in the extinct forms they may be either amphicœlous (concave at both ends) or opisthocœlous (concave behind). The vertebral ends of the anterior trunk-ribs are bifurcate. There are two sacral vertebræ. The cervical vertebræ have small ribs (hence the difficulty experienced by the animal in turning quickly); and there are generally false abdominal ribs produced by the ossification of the tendinous intersections of the *recti* muscles. There are no clavicles. The sternum is rhomboidal and cartilaginous, sending backwards a pair of "xiphoid" processes. On its face, anteriorly, is a bony "interclavicle," while a scapula and coracoid exist on each side. *The heart consists of four completely distinct and separate cavities, two auricles, and two ventricles; the ventricular septum—as in no other Reptiles—being complete. The right and left aortæ, however—or, in other words, the pulmonary artery and systemic aorta—are connected together close to their origin by a small aperture (foramen Panizzæ), so that the two sides of the heart communicate with one another. The aperture of the cloaca is longitudinal, and not transverse as in the Lizards. All the four limbs are present, the anterior ones being pentadactylous, the posterior tetradactylous. All are oviparous.*

The chief points by which the Crocodiles are distinguished from their near allies the Lacertilians, are the possession of a partial bony dermal exoskeleton in addition to the ordinary epidermic covering of scales, the lodgment of the teeth in

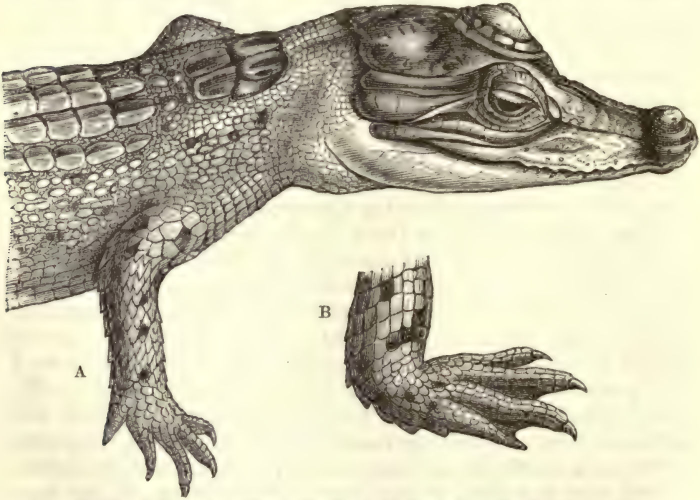

Fig. 309.—A, Head and anterior portion of the body of *Crocodilus pondicerianus*; B, Hind-foot of the same. (After Günther.)

distinct sockets, and the fact that the mixture of venous and arterial blood, which is so characteristic of Reptiles, takes place, not in the heart itself, but in its immediate neighbourhood, by a communication between the pulmonary artery and aorta directly after their origin.

When the exoskeleton is complete (as in Caiman), it consists of transverse rows of quadrate bony plates disposed so as to form a distinct dorsal and ventral shield, which are separated by soft skin in the region of the trunk, but become confluent in the tail. All the scutes of one row are united by suture, and successive rows usually movably overlap one another.

'The only other points about the Crocodiles which require special notice are, that the eyes are protected by movable eye-lids; the ear is covered by a movable ear-lid; the nasal cavities open in front by a single nostril, and are shut off from the cavity of the mouth, but open far back into the cavity of the pharynx; and lastly, the tongue is large and fleshy, and is immovably attached to the bottom of the mouth. (Hence the belief of the ancients that the Crocodile had no tongue). The tail is long and compressed, with two rows of keeled plates, which unite about its middle to form a single crest, which is continued to its extremity. The feet are palmate or semipalmate, and only the three inner toes on each foot possess claws. The eyes possess three distinct lids, and there are two glands under the throat secreting a musky substance.

The *Crocodilia* abound in the fresh waters of hot countries, and are the largest of all living Reptiles, not uncommonly attaining the length of twenty feet or upwards.

They are divided by Owen into three sub-orders, according to the shape of the dorsal vertebræ, termed the *Procœlia*, *Amphicœlia*, and *Opisthocœlia.*

Sub-order I. *Procœlia.*—In this sub-order are all the living members of the *Crocodilia*, distinguished by having the bodies of the dorsal vertebræ concave in front (procœlous). Three distinct types may be distinguished amongst the living *Crocodilia*. The Gavial is distinguished by its elongated snout, at the extremity of which the nostril is placed, and by the fact that the teeth are pretty nearly equal in size and similar in form in the two jaws. In the true Crocodiles (fig. 310) the fourth tooth in the lower jaw is larger than the others, and forms a canine tooth, which is received into a notch excavated in the side of the alveolar border of the upper jaw, so that it is visible externally when the mouth is closed. In the Caimans or Alligators the same tooth in the lower jaw forms a canine, but it is received into a pit in the palatal surface of the upper jaw, where it is entirely concealed when the mouth is shut. The Crocodiles have the hind-legs bordered by a toothed fringe, and the toes completely united by membrane. They are essentially natives of fresh water, but sometimes frequent the mouths of rivers. They occur chiefly in Asia and Africa, but species are found in some of the West Indian Islands. The Alligators have the hind-legs simply rounded, and the feet not completely webbed. They are essentially aquatic, and are voracious animals, living upon fish or Mammals. The best-known species are the Alligator of the southern United States (*A. Mississippiensis*), the Caiman (*A. palpebrosus*) of Surinam and Guiana, and the "Jacaré" or Spectacled Alligator (*A. sclerops*) of Brazil. The Gavials inhabit fresh waters, and appear to be exclusively confined to the Ganges and other large rivers of India. The Gangetic form (*Gavialis Gangeticus*), in spite of its numerous pointed teeth, is not so highly carnivorous as the true Crocodiles.

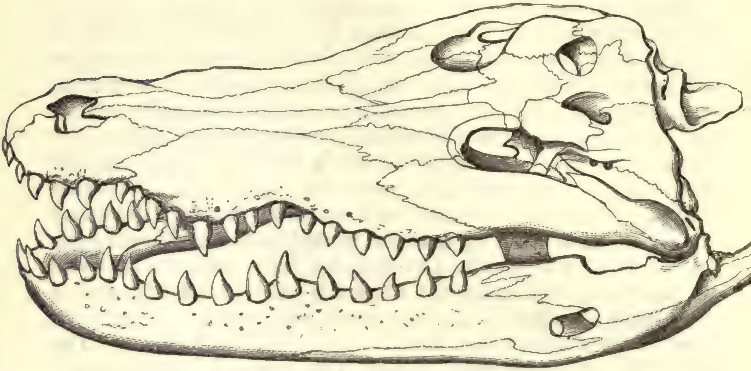

Fig. 310.—Skull of the Crocodile.

True procœlian Crocodiles occur for the first time in the Greensand (Cretaceous series) of North America. In Europe, however, the earliest remains of procœlian Crocodiles are from the Lower Tertiary rocks (Eocene). It is a curious fact that in the Eocene rocks of the south-west of England, there occur fossil remains of all the three living types of the *Crocodilia*—namely, the Gavials, true Crocodiles, and Alligators; though at the present day these forms are all geographically restricted in their range, and are very partially associated together.

Sub-order 2. *Amphicœlia.*—The Amphicœlian Crocodiles, with biconcave vertebræ, are entirely extinct. They have but a limited geological range, extending only from the Trias to the Chalk inclusive, and being therefore strictly Mesozoic. The biconcave vertebræ show a decided approach to the structure of the backbone in fishes; and as the rocks in which they occur are marine, there can be little doubt but that these Crocodiles were, in the majority of cases at any rate, marine. The most important genera belonging to this order are *Teleosaurus*, *Belodon*, *Stagonolepis*, *Steneosaurus*, *Dakosaurus*, *Makrospondylus*, and *Suchosaurus*, the last being from the fresh-water deposits of the Wealden (Cretaceous).

Sub-order 3. *Opisthocœlia.*—The sub-order of the *Opisthocœlian* Crocodiles, including those forms in which the anterior trunk vertebræ are concave behind, is one which can be only provisionally retained. Professor Owen includes in this section the two genera *Streptospondylus* and *Cetiosaurus;* but the latter is referable to the *Deinosauria*, and will be treated of when that order is considered. The genus *Streptospondylus* has been founded on vertebræ obtained from the Oolitic and Wealden formations; but there are doubts as to the true position of the reptile to which these belonged.

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CHAPTER LXII.

EXTINCT ORDERS OF REPTILES.

It remains now to consider briefly the leading characters of six wholly extinct orders of Reptiles, the peculiarities of which are very extraordinary, and are such as are exhibited by no living forms.

Order V. Ichthyopterygia, Owen (= *Ichthyosauria*, Huxley). The gigantic Saurians forming this order were distinguished by the following characters:—

The body was fish-like, without any distinct neck, and probably covered with a smooth or wrinkled skin, no horny or bony exoskeleton having been ever discovered. The vertebræ were numerous, deeply biconcave or amphicœlous, and having the neural arches united to the centra by a distinct suture. The anterior trunk-ribs possess bifurcate heads. There is no sacrum, and no sternal ribs or sternum, but clavicles were present as well as an interclavicle (episternum); and false ribs were developed in the walls of the abdomen. The skull had enormous orbits separated by a septum, and an elongated snout. The eyeball was protected by a ring of bony plates in the sclerotic (fig. 313). *The teeth were not lodged in distinct sockets, but in a common alveolar groove. The fore and hind limbs were converted into swimming-paddles, the ordinary number of digits (five) remaining recognisable, but the phalanges being greatly increased in number, and marginal ossicles being added as well. A vertical caudal fin was in all probability present.*

The order *Ichthyopterygia* includes only, or principally, the gigantic and fish-like *Ichthyosauri* (fig. 311), all exclusively Mesozoic, and abounding in the Lias, Oolites, and Chalk, but especially characteristic of the Lias. If, however, the *Eosaurus Acadiensis* (Marsh) of the Coal-measures of Nova Scotia be rightly referred to this order, then the *Ichthyopterygia* date from the Carboniferous period. Moreover, Prof. Marsh has recently

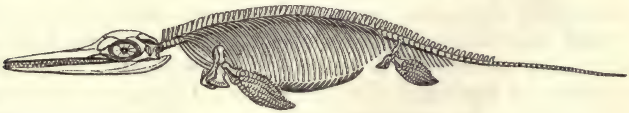

Fig. 311.—*Ichthyosaurus communis.*

described, from the Jurassic deposits of North America, a Reptile, which he has named *Sauranodon*, and which agrees in all important respects with *Ichthyosaurus*, except that *it has*

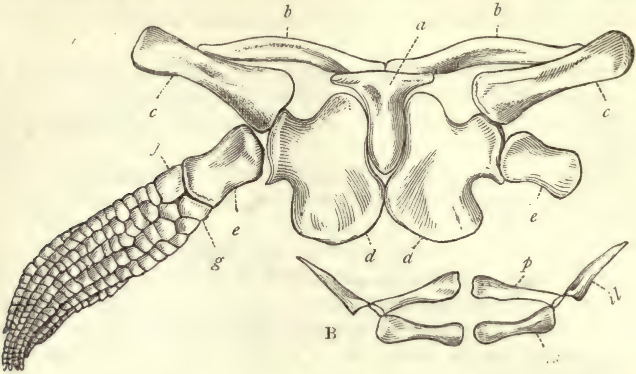

Fig. 312.—A, Pectoral arch and fore-limbs of *Ichthyosaurus*: *a* Interclavicle; *b b* Clavicles; *c c* Scapulæ; *d d* Coracoids; *e* Humerus; *f* Radius; *g* Ulna. (Somewhat altered from Huxley.) B, Pelvis of *Ichthyosaurus*: *p* Pubis; *il* Ilium; *is* Ischium.

no teeth. Prof. Marsh regards it as the type of a new order, but we may in the meanwhile include it here. There is no doubt whatever but that the *Ichthyosauri* were essentially marine animals, and they have been often included with the next order (*Sauropterygia*) in a common group, under the name of *Enaliosauria* or Sea-lizards.

In the biconcave vertebræ and probable presence of a vertical tail-fin, the *Ichthyosaurus* approaches the true fishes. There is, however, no doubt as to the fact that the animal was strictly an air-breather, and its reptilian characters cannot be questioned, at the same time that the conformation of the limbs is decidedly Cetacean in many respects. Much has been gathered from various sources as to the habits of the *Ichthyosaurus*, and its history is one of great interest. From the researches of Buckland, Conybeare, and Owen, the following facts appear to be pretty well established: That the *Ichthyosauri* kept chiefly to open waters may be inferred from their strong and well-developed swimming apparatus. That they occasionally had recourse to the shore, and crawled upon the beach, may be safely inferred from the presence of a strong and well-developed bony arch, supporting the fore-limbs, and somewhat resembling in structure the scapular arch of the *Ornithorhynchus* or Duck-mole of Australia. That they lived in stormy seas, or were in the habit of diving to considerable depths, is shown by the presence of a ring of bony plates in the sclerotic, protecting the eye from injury or pressure (fig. 313). That they possessed extraordinary powers of vision,

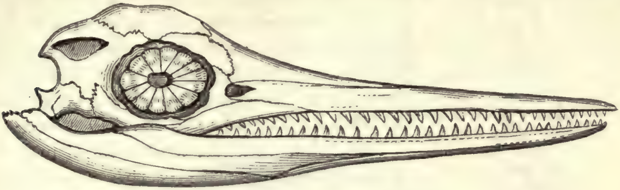

Fig. 313.—Skull of *Ichthyosaurus*, showing the sclerotic plates.

especially in the dusk, is certain from the size of the pupil, and from the enormous width of the orbits. That they were carnivorous and predatory in the highest degree is shown by the wide mouth, the long jaws, and the numerous, powerful, and pointed teeth. This is proved, also, by an examination of their petrified droppings, which are known to geologists as "coprolites," and which contain numerous fragments of the scales and bones of the Ganoid fishes which inhabited the same seas.

ORDER VI. SAUROPTERYGIA, Owen (= *Plesiosauria*, Huxley). This order of extinct reptiles, of which the well-known *Plesiosaurus* may be taken as the type, is characterised by the following peculiarities:—

The body, as far as is known, was naked, and not furnished with any horny or bony exoskeleton. The bodies of the vertebræ were either flat or only slightly cupped at each end, and the neural arches were anchylosed with the centra, and did not remain distinct during life. The transverse processes of the vertebræ were long, and the anterior trunk-ribs had simple, not bifurcate heads. No sternum or sternal ribs are known to have existed, but there were false abdominal ribs. The neck (fig. 314) *in most was greatly elongated, and composed of numerous vertebræ. The sacrum was composed of two vertebræ. The orbits were of large size, and there*

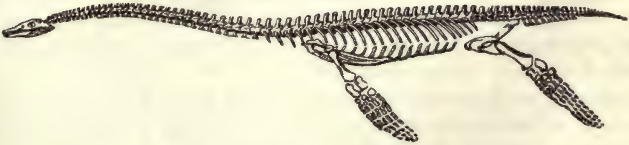

Fig. 314.—*Plesiosaurus dolichodeirus.*

was a long snout, as in the Ichthyosauri, but there was no circle of bony plates in the sclerotic. The limbs agree with those of the Ichthyosauri in being in the form of swimming-paddles (fig. 315), *but differ in not possessing any supernumerary marginal ossicles. A pectoral arch, formed of two clavicles and an interclavicle (episternum), appears to have been sometimes, if not always, present. The teeth were simple, and were inserted into distinct sockets, and not lodged in a common groove.*

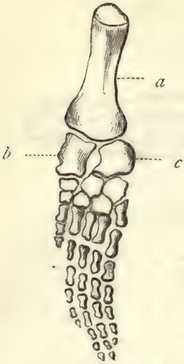

Fig. 315.—Left fore-paddle of *Plesiosaurus*. *a* Humerus; *b* Radius; *c* Ulna.

The most familiar and typical member of the *Sauropterygia* is the *Plesiosaurus* (fig. 314), a gigantic marine reptile, chiefly characteristic of the Lias and Oolites. As regards the habits of the *Plesiosaurus*, Dr Conybeare arrives at the following conclusions : " That it was aquatic is evident from the form of its paddles ; that it was marine is almost equally so from the remains with which it is universally associated ; that it may have occasionally visited the shore, the resemblance of its extremities to those of the Turtles may lead us to conjecture ; its movements, however, must have been very awkward on land ; and its long neck must have impeded its progress through the water, presenting a striking contrast to the organisation which so admirably fits the *Ichthyosaurus* to cut through the waves." As its respiratory organs were such that it must of necessity have required to obtain air frequently, we may conclude " that it swam upon or near the surface, arching back its long neck like a swan, and occasionally darting it down at the fish which happened to float within its reach. It may, perhaps, have lurked in shoal water along the coast, concealed amongst the sea-weed ; and raising its nostrils to a level with the surface from a considerable depth, may have found a secure retreat from the assaults of powerful enemies ; while the length and flexibility of its neck may have compensated for the want of strength in its jaws, and its incapacity for swift motion through the water."

The geological range of the *Plesiosaurus* is from the Lias to the Chalk inclusive, and specimens have been found indicating a length of from eighteen to twenty feet.

Of the other genera of the *Sauropterygia*, *Simosaurus* and *Nothosaurus* are from the Trias, and are chiefly characteristic of its middle division, the Muschelkalk. *Placodus* is another genus, also from the Muschelkalk, and is characterised by the extraordinary form of the teeth, which resembled those of many fishes in forming broad crushing plates, constituting a kind of pavement.

Order VII. Anomodontia, Owen (= *Dicynodontia*, Huxley). The leading characters of this order are to be found in the structure of *the jaws, which appear to have been sheathed in horn so as to constitute a kind of beak, very like that of the Chelonians.* In the genus *Oudenodon* (fig. 316), both jaws seem to have been altogether destitute of teeth; but in *Dicynodon* (fig. 316) there were two long tusks, growing from persistent pulps, placed one on each side in the upper jaw. *The pectoral and pelvic arches were very strong, and the limbs were well developed and fitted for walking, and not for swimming.*

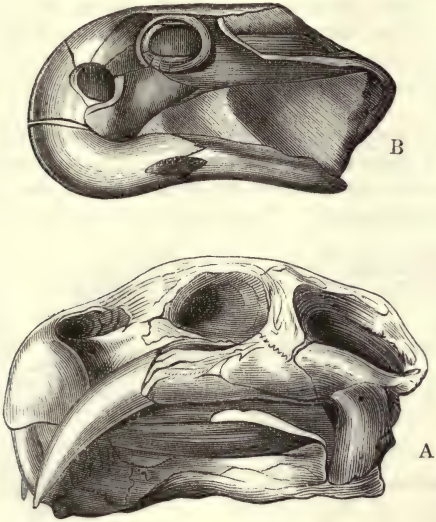

Fig. 316.—A, Skull of *Dicynodon lacerticeps*, showing the maxillary tusk. B, Skull of *Oudenodon Bainii*. From the Trias of South Africa. (After Owen.)

Dicynodon and *Oudenodon* are known only from strata of supposed Triassic age in South Africa and India, but *Rhynchosaurus* occurs in the Trias of Europe. This last genus, however, is placed by Huxley amongst the *Lacertilia*.

Order VIII. Pterosauria (*Ornithosauria*, Seeley).—This order includes a group of extraordinary flying Reptiles, all belonging to the Mesozoic epoch, and exhibiting in many respects a very extraordinary combination of characters. The most familiar members of the order are the so-called "Pterodactyles," and the following are the characters of the order:—

No exoskeleton is known to have existed. The dorsal vertebræ are procœlous, and the anterior trunk-ribs are double-headed. There is a broad sternum with a median ridge or keel, and ossified sternal ribs. The jaws were generally armed with teeth, and these were implanted in distinct sockets. In some forms (*Ramphorhynchus*) there appear to have been no teeth in the anterior portion of the jaws, and these parts seem to have been sheathed in horn, so as to constitute a kind of beak. In the genus *Pteranodon*, from the Cretaceous rocks of North America, comprising gigantic examples of the order, the jaws are completely destitute of teeth, and appear to have been encased in a horny beak.

A ring of bony plates occurs in the sclerotic coat of the eye. The pectoral arch consists of a scapula and distinct coracoid bone, articulating with the sternum as in Birds, but no clavicles have hitherto been discovered. The fore-limb (fig. 317) *consists of a humerus, ulna and radius, carpus, and hand of four fingers, of which the inner three are short and unguiculate, whilst the outermost is clawless and is enormously elongated. Between this immensely-lengthened finger, the side of the body, and the comparatively small hind-limb, there must have been supported an expanded flying-membrane, or "patagium," which the animal must have been able to employ as a wing, much as the bats of the present day. Lastly, most of the bones were "pneumatic"—that is to say, were hollow and filled with air.*

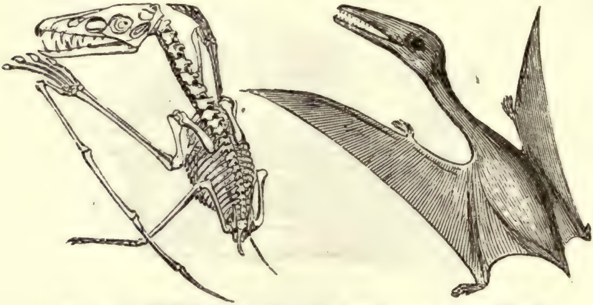

Fig. 317.—*Pterodactylus brevirostris.* Skeleton and restoration.

By the presence of teeth in distinct sockets, and, as will be seen hereafter, especially in the structure of the limbs, the Pterodactyles differed from all known Birds, and there can be little question as to their being genuine Reptiles. The only Reptiles, however, now existing, which possess any power of sustaining themselves in the air, are the little Dragons (*Draco*), but these can only take extended leaps from tree to tree, and cannot be said to have any power of flight properly so called. That the Pterodactyles, on the other hand, possessed the power of genuine flight, is shown by the presence of a median keel upon the sternum, proving the existence of unusually developed pectoral muscles; by the articulation of the coracoid bones with the top of the sternum, providing a fixed point or fulcrum for the action of the pectoral muscles; and, lastly, by the existence of air-cavities in the bones, giving the animal the necessary degree of lightness. The apparatus, however, of flight was not a "wing," as in Birds, but a flying membrane, very similar in its mode of action to the patagium of the Mammalian order of the Bats. The patagium of the Bats, however, differs from that of the Pterodactyles in being supported by the greatly-elongated fingers, whereas in the latter it is only the outermost finger which is thus lengthened out. The difficulty as to the position of the *Pterosauria* is evaded by Mr Seeley by placing them in a distinct class, which he terms *Ornithosauria*, and which he regards as most nearly related to, but coequal with, the class *Aves*.

The *Pterosauria* are exclusively Mesozoic, being found from the Lower Lias to the Chalk inclusive, the Lithographic Slate of Solenhofen (Upper Oolite) being particularly rich in their remains. Most of them appear to have attained no very great size, but the remains of a species from the Cretaceous rocks have been considered to indicate an animal with more than twenty feet expanse of wing, counting from tip to tip.

In the genus *Pterodactylus* proper, the jaws are provided with teeth to their extremities, all the teeth being long and slender.

In *Dimorphodon*, the anterior teeth are large and pointed, the posterior teeth small and lancet-shaped.

In *Ramphorhynchus*, the anterior portion of both jaws is edentulous, and may have formed a horny beak, but teeth are present in the hinder portion of the jaws.

In *Pteranodon*, lastly, the jaws are completely edentulous, and were probably ensheathed in horn. This genus, along with some small forms, includes the largest known members of the order.

ORDER IX. DINOSAURIA, or DEINOSAURIA.—The last order of extinct Reptiles is that of the *Dinosauria*, comprising a group of very remarkable Reptiles, which are in some respects intermediate in their characters between the Struthious Birds and the typical Reptiles; whilst they have been supposed to have affinities to the Pachydermatous Mammals. Most of the *Dinosauria* were of gigantic size, and the order is defined by the following characters:—

The skin was sometimes naked, sometimes furnished with a well-developed exoskeleton, consisting of bony shields, much resembling those of the Crocodiles. A few of the anterior vertebræ were opisthocœlous, the remainder having flat or slightly biconcave bodies. The anterior trunk-ribs were double-headed. The teeth were confined to the jaws and implanted in distinct sockets. There were always two pairs of limbs, and these were strong, furnished with claws, and adapted for terrestrial progression. In some cases the fore-limbs were very small in proportion to the size of the hind-limbs. No clavicles have been discovered.

The teeth are sometimes implanted in distinct sockets, and they are never anchylosed with the jaws. The ischium and pubes are much elongated; the inner wall of the acetabulum is formed by membrane; the tibia has its proximal end prolonged anteriorly into a strong crest; and the astragalus is bird-like (Huxley).

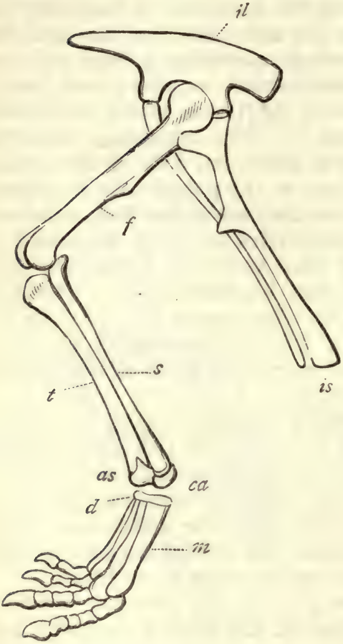

Fig. 318.—Leg of Deinosaur. *il* Ilium; *is* Ischium; *f* Femur; *t* Tibia; *s* Fibula; *as* Astragalus; *ca* Calcaneum; *m* Metatarsus. (After Huxley.)

The most remarkable points in the organisation of the *Dinosauria* are connected with the structure of the pelvis and hind-limb, the characters of which, as pointed out by Huxley, approximate to those of the same parts in the Birds, and especially in the Struthious Birds. This approximation is especially seen in the prolongation of the ilium in front of the acetabulum (fig. 318), the elongation and slenderness of form of the ischium, and the slenderness of the pubes. The astragalus is like that of a bird, and in some cases appears to have become anchylosed with the distal end of the tibia. The metatarsal bones, however, remain distinct, and are not anchylosed with any of the tarsal bones to form a "tarso-metatarsus."

The most familiar examples of the *Dinosauria* are *Megalosaurus* and *Iguanodon*.

Megalosaurus is a gigantic Oolitic Reptile, which occurs also in the Cretaceous series (Weald Clay). Its length has been estimated at between forty and fifty feet, the femur and tibia each measuring about three feet in length. As the head of the femur is set on nearly at right angles with the shaft, whilst all the long bones contain large medullary cavities, there can be no doubt but that *Megalosaurus* was terrestrial in its habits. That it was carnivorous and destructive in the highest degree is shown by the powerful, pointed, and trenchant teeth.

The *Iguanodon* is mainly, if not exclusively, Cretaceous, being especially characteristic of the great delta-deposit of the Wealden. The length of the *Iguanodon* has been estimated as being probably from fifty to sixty feet; and from the close resemblance of its teeth to those of the living Iguanas, there is little doubt that it was herbivorous and not carnivorous. The femur of a large *Iguanodon* measures from four to five feet in length, with a circumference of twenty-two inches in its smallest part. From the disproportionately small size of the fore-limbs, and from the occurrence of *pairs* of gigantic three-toed footsteps in the same beds, it has been concluded, with much probability, that *Iguanodon*, in spite of its enormous bulk, must have walked temporarily or permanently upon its hind-legs, thus coming to present a most marked and striking affinity to the Birds.

The most remarkable, however, of the *Dinosauria*, is the little *Compsognathus longipes*, from the Lithographic Slate of Solenhofen, referred to this order by Professor Huxley. This Reptile is not remarkable for its size, which does not seem to have been much more than two feet, but for the singular affinities which it exhibits to the true Birds. The head of *Compsognathus* was furnished with *toothed* jaws, and supported upon a long and slender neck. The fore-limbs were very short, but the hind-limbs were long and like those of Birds. The *proximal* portion of the tarsus resembled that of Birds in being anchylosed to the lower end of the tibia; but the *distal* portion of the tarsus—unlike that of Birds—was free, and was not anchylosed with the metatarsus. Huxley concludes that "it is impossible to look at the conformation of this strange Reptile, and to doubt that it hopped or walked in an erect or semi-erect position, after the manner of a Bird, to which its long neck, slight head, and small anterior limbs must have given it an extraordinary resemblance."

The researches of Professor Phillips, further, have now shown that the gigantic *Cetiosaurus* of the Oolitic and Cretaceous rocks, formerly referred to the *Crocodilia*, is truly a Deinosaur. Its total length is estimated at probably not less than sixty or seventy feet.

ORDER X. THERIODONTIA.—This order has been founded by Professor Owen for the reception of a number of carnivorous Reptiles from deposits of Triassic or Permian age. The Reptiles in question show some singular Mammalian affinities, especially to the Beasts of Prey. *The dentition is of the carnivorous type, the teeth being in three distinct sets—viz., incisors, canines, and molars, and the canines being large and pointed.*

In *Cynodraco*, which may be regarded as the type of the group, the canines are not only of immense size, but are compressed in shape, and have the hinder trenchant border of the tooth minutely serrated, thus resembling the canines of the Sabre-toothed Tiger (*Machairodus*). The humerus is, further, furnished with a "supra-condyloid foramen" (similar to that of the humerus of *Felidæ* and other carnivorous Mammals) for the protection of the median nerve and brachial artery on their way down the arm. Whilst *Cynodraco* is the type of the *Theriodontia*, Prof. Owen is of opinion that a number of other genera (such as *Galesaurus*, *Cynochampsa*, *Lycosaurus*, &c.), principally of Triassic age, are likewise referable to the same order.

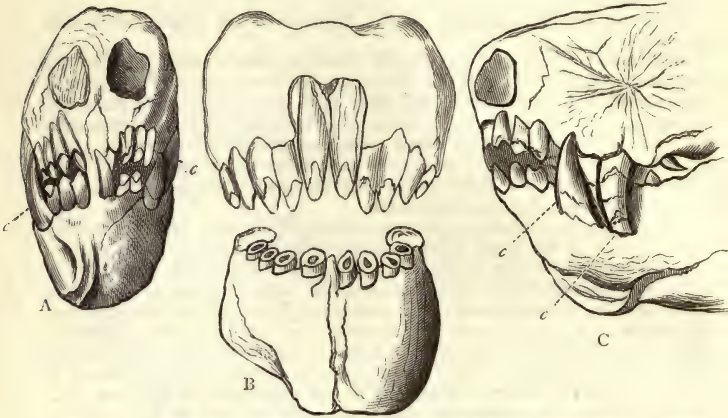

Fig. 319.—A, Front view of the skull of *Lycosaurus*, showing the dentition. B, Front view of the jaws of *Cynodraco serridens*, showing the incisor teeth. C, Side view of the jaws of *Lycosaurus*, showing the incisors and the laniariform canines; *c* Canines. (After Owen.)

LITERATURE.

[In addition to most of the systematic works quoted at p. 441, the following are some of the more important sources of information as to the structure of recent and fossil Reptiles :—]

1. "Erpétologie générale, ou histoire naturelle complète des Reptiles." Dumeril and Bibron. 1834-54.

2. "Reptiles of British India." Günther. 'Ray Society.' 1864.

3. "Catalogue of Colubrine Snakes, Lizards, &c., in the British Museum." Günther. 1844-58.

4. "Catalogue of the Shield Reptiles in the British Museum." J. E. Gray. 1855.

5. "Monograph of the Testudinata." Bell. 'Ray Society.' 1836.

6. "Anatomia Testudinis Europeæ." Bojanus. 1819-21.

7. "History of British Reptiles." Bell. 1839.

8. "Histoire des Quadrupèdes ovipares." Lacépède. 1788-89.

9. "Histoire naturelle des Reptiles." Daudin. 1802.

10. "Systema Reptilium." Fitzinger. 1843.

11. "Anatomie und Naturgeschichte des Drachen." Tiedemann. 1811.

12. Article "Reptilia." Rymer Jones. 'Todd's Cyclopædia of Anatomy and Physiology.' 1847-49.

13. "North American Herpetology." Holbrook. 1836-43.

14. "Catalogue of North American Reptiles." Baird and Girard. 1853.

15. "Homologies of some of the Cranial Bones of the Reptilia, and on the Systematic Arrangement of the Class." Cope. 'Amer. Assoc. for the Advancement of Science.' 1870.

16. "Thanatophidia of India." Fayrer.

17. "On Hatteria." Günther. 'Phil. Trans.' 1867.

18. "Odontography." Owen. 1840-45.

19. "Entwickelungsgeschichte der Natter." Rathke. 1837.

20. "Entwickelung der Schildkröten." Rathke. 1848.

21. "Entwickelung und Körperbau der Krokodile." Rathke. 1866.

22. "Saurier des Muschelkalkes." Von Meyer.

23. "Saurier aus dem Kupfer-Schiefer der Zechstein-formation." Von Meyer.

24. "Report on Fossil Reptiles." Owen. 'Brit. Assoc. Reports.' 1841.

25. "On Dicynodon." Owen. 'Trans. Geol. Soc.' 1845.

26. "Descriptive Catalogue of the Fossil Reptilia and Fishes in the Museum of the Royal College of Surgeons of England." Owen.

27. "Catalogue of the Fossil Reptiles of South Africa in the Collections of the British Museum." Owen. 1876.

28. "Monographs of the Fossil Reptiles of the Jurassic Formation of Britain." Owen. 'Palæontographical Society.' 1859, 1861, 1862, 1863, 1869, 1870.

29. "Monographs of the Fossil Reptiles of the Cretaceous Formations of Britain." Owen. 'Palæontographical Society.' 1851, 1853, 1855, 1856, 1857, 1858, 1859, 1863, and 1872.

30. "Monograph of the Cretaceous Reptiles of the London Clay." Owen and Bell. 'Palæontographical Society.' 1849.

31. "On a Carnivorous Reptile (Cynodraco major), &c." Owen. 'Quart. Journ. Geol. Soc.' 1876.

32. "On Evidences of Theriodonts in Permian Deposits." Owen. 'Quart. Journ. Geol. Soc.' 1876.

33. "On the Stagonolepis Robertsoni." Huxley. 'Quart. Journ. Geol. Soc.' 1859.

34. "On a new Specimen of Telerpeton Elginense." Huxley. 'Quart. Journ. Geol. Soc.' 1866.

35. "On Hyperodapedon." Huxley. 'Quart. Journ. Geol. Soc.' 1869.

36. "On the Affinities between the Deinosaurian Reptiles and Birds." Huxley. 'Quart. Journ. Geol. Soc.' 1870.

37. "On the Classification of the Deinosauria," &c. Huxley. 'Quart. Journ. Geol. Soc.' 1870.

38. "Catalogue of Ornithosauria." Seeley.
39. "Geology of Oxford and the Thames Valley." Phillips. 1871.
40. "Structure of the Skull and Limbs in Mosasauroid Reptiles." Marsh. 'Amer. Journ. Sci. and Arts.' 1872.
41. "Cretaceous Reptiles of the United States." Leidy. 'Smithsonian Contributions to Knowledge,' vol. xiv.
42. "Synopsis of Extinct Batrachia and Reptilia of North America." Cope.

DIVISION II.—SAUROPSIDA.

CHAPTER LXIII.

CLASS IV.—AVES.

THE fourth class of the *Vertebrata* is that of *Aves*, or Birds. The Birds may be shortly defined as being "oviparous Vertebrates with warm blood, a double circulation, and a covering of feathers" (Owen). More minutely, however, the Birds are defined by the possession of the following characters:—

The embryo possesses an amnion and allantois, and branchiæ or gills are never developed at any time of life upon the visceral arches. The skull articulates with the vertebral column by a single occipital condyle. The form of the vertebral centra varies; but they are in no case amphicœlous, except in the remarkable extinct form described under the name of *Ichthyornis*. Each half or ramus of the lower jaw consists of a number of pieces, which are separate from one another in the embryo; and the jaw is united with the skull, not directly, but by the intervention of a quadrate bone (as in the Reptiles). The fore-limb in no existing birds possesses more than three fingers or digits, and the metacarpal bones are anchylosed together. In all living birds the fore-limbs are useless as regards prehension, and in most they are organs of flight. The hind-limbs in all birds have the ankle-joint placed in the middle of the tarsus, the proximal portion of the tarsus coalescing with the tibia, and the distal portion of the tarsus being anchylosed with the metatarsus to constitute a single bone known as the "tarso-metatarsus."

The heart consists of four chambers, two auricles, and two ventricles; and not only are the right and left sides of the heart completely separated from one another, but there is no communication between the pulmonary and systemic circulations, as there is in Reptiles. There is only one aortic arch, the right. The blood is hot, having an average temperature of as much as 103° to 104°. The blood-corpuscles are oval and nucleated.

The respiratory organs are in the form of spongy cellular lungs, which are not freely suspended in pleural sacs; and the bronchi open on their surface into a number of air-sacs, placed in different parts of the body.

All birds are oviparous, none bringing forth their young alive, or being even ovo-viviparous. All birds are, lastly, provided with an epidermic covering, so modified as to constitute what are known as *feathers*.

Professor Huxley's account of the method in which feathers are produced is so remarkably clear, that no apology is necessary for quoting it in its entirety. Feathers "are evolved within sacs from the surface of conical papillæ of the dermis. The external surface of the dermal papilla, whence a feather is to be developed, is provided upon its dorsal surface with a median groove, which becomes shallower towards the apex of the papilla. From this median groove lateral furrows proceed at an open angle, and passing round upon the under surface of the papilla, become shallower, until, in the middle line, opposite the dorsal median groove, they become obsolete. Minor grooves run at right angles to the lateral furrows. Hence the surface of the papilla has the character of a kind of mould, and if it were repeatedly dipped in such a substance as a solution of gelatine, and withdrawn to cool until its whole surface was covered with an even coat of that substance, it is clear that the gelatinous coat would be thickest at the basal or anterior end of the median groove, at the median ends of the lateral furrows, and at those ends of the minor grooves which open into them; whilst it would be very thin at the apices of the median and lateral grooves, and between the ends of the minor grooves. If, therefore, the hollow cone of gelatine, removed from its mould, were stretched from within, or if its thinnest parts became weak by drying, it would tend to give way, along the inferior median line, opposite the rod-like cast of the median groove, and between the ends of the casts of the lateral furrows, as well as between each of the minor grooves, and the hollow cone would expand into a flat feather-like structure, with a median shaft, and a 'vane' formed of 'barbs' and 'barbules.' In point of fact, in the development of a feather, such a cast of the dermal papilla is formed, though not in gelatine, but in the horny epidermic layer developed upon the mould, and as this is thrust outwards, it opens out in the manner just described. After a certain period of growth the papilla of the feather ceases to be grooved, and a continuous horny cylinder is formed, which constitutes the 'quill.'"

A typical feather (fig. 320) consists of the following parts:— 1. The "quill" or "calamus" (*a*), which forms the basal portion of the feather, by which it is inserted in the skin on its own dermal papilla. It is the latest-formed portion of the feather, and consists of a hollow horny cylinder. 2. The "shaft" or "rachis" (*b*), which is simply a continuation of the quill, and which forms the central axis of the feather. The inferior surface of the shaft always exhibits a strong longitudinal groove, and it is composed of a horny external sheath, containing a white spongy substance, very like the pith of a plant. 3. The shaft carries the lateral expansions or "webs" of the feather, collectively constituting the "vane" or "vexillum." Each web is composed of a number of small branches, which form an open angle with the shaft, and which are known as the "barbs" (*c*). The margins of each barb are, in turn, furnished with a series of still smaller branches, which are known as the "barbules." As a general rule, the extremities of the barbules are hooked, so that those springing from the one side of each barb interlock with those springing from the opposite side of the next barb. In this way the barbs are kept in apposition with one another over a greater or less portion of the entire web. More or less of the barbs in the lower portion of the feather are, however, disunited, and not connected by their barbules; and these constitute what is known as the "down." In the Ostriches, Emeus, and some others, all the barbs of the feathers are disconnected, giving to the plumage of these birds its peculiarly soft character. At the point where the shaft joins the quill, and on the under side of the former, there is very generally found a small feather, known as the "accessory plume," or "after-shaft" ("hyporachis"). This is usually much the same in structure as the main feather, but considerably smaller. It may, however, be as large as the original feather, or it may be reduced to nothing more than a tuft of down.

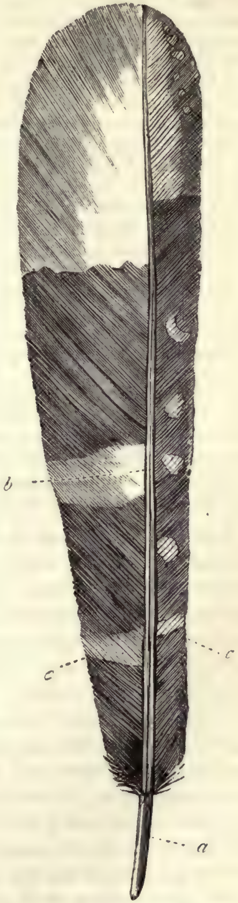

Fig. 320.—Quill-feather (*Stenopsis*). *a* Quill or barrel; *b* Shaft; *c c* Webs, composed of the barbs, and together forming the "vane."

The feathers vary in different parts of the bird, and are generally divided into those which cover the body—"clothing feathers"—and those which occur in the wings and tail—"quill-feathers." As regards the great quill-feathers of the wings, the longest are those which arise from the bones of the hand, and they are called the "primaries." Those which arise from the distal end of the fore-arm (radius and ulna) are termed the "secondaries," and those which are attached to the proximal end of the fore-arm are the "tertiaries." The feathers which lie over the humerus and scapula are the "scapulars." The rudimentary "thumb" also carries some quills, which form what is known as the "alula," or "bastard-wing." The smaller feathers, which cover the bases of the quill-feathers above and below, are the "wing-coverts"—"greater," "lesser," and "under." The great quill-feathers of the tail ("rectrices") form a kind of fan, of great use in steering the bird in flight; and their bases are covered by a series of feathers which constitute the "tail-coverts." Generally there are ten or twelve "rectrices;" but there may be as many as twenty-four (as in the Pelican), or rarely more; and they do not carry "accessory plumules." In addition to the "clothing-feathers" and the quill-feathers of the wings and tail, the body is protected by a more or less abundantly developed coating of "down-feathers" ("plumulæ"), in which the barbules are not hooked, and the barbs are therefore free. In some cases there is no shaft to the down-feathers, and the barbs are attached in a tuft to the end of the quill. In other cases, the feathers closely approximate to hairs in form, being very long, slender, and flexible. These "filoplumæ" consist of a delicate shaft, either destitute of vanes, or carrying a few barbs at the extremity.

Though apparently completely covered with feathers, these appendages are really almost always confined to certain special tracts ("pterylæ") in the body of a bird, the intervening spaces ("apteria") being, with few exceptions, naked. These feathered and unfeathered regions are definite in form, size, and arrangement in many great groups of birds, and can thus be used as an important aid to classification.

The entire *skeleton* of the Birds is singularly compact, and at the same time singularly light. The compactness is due to the presence of an unusual amount of phosphate of lime; and the lightness, to the absence in many of the bones of the ordinary marrow, and its replacement by air.

As regards the *vertebral column*, birds exhibit some very interesting peculiarities. The cervical region of the spine is unusually long and flexible, since the fore-limbs are useless as organs of prehension, and all acts of grasping must be exercised either by the beak or by the hind-feet, or by both acting in conjunction. In all birds alike, the neck is sufficiently long and flexible to allow of the application of the beak to an oil-gland placed at the base of the tail, this act being necessary for the due performance of the operation of "preening"—that is, of lubricating and cleaning the plumage. The cervical vertebræ vary in number from eight to twenty-three. The front faces of their centra are cylindroidal (spheroidal in Penguins), *convex from above downwards, and concave from side to side*, the posterior faces being *saddle-shaped*, concave from above downwards and convex from side to side. Hence in *vertical* section, the vertebræ appear to be *opisthocœlous*, and in *horizontal* section *procœlous*. This structure of the cervical vertebræ is highly characteristic of Birds. The dorsal vertebræ vary from six to ten in number, and of these the anterior four or five are generally anchylosed with one another, so as to give a base of resistance to the wings. In the Cursorial Birds, however (such as the Ostrich and Emeu), and in some others (such as the Penguin), in which the power of flight is wanting, the dorsal vertebræ are all more or less freely movable one upon another. There are no lumbar vertebræ, but all the vertebræ between the last dorsal and the first caudal (varying from nine to twenty) are anchylosed together to form a bone which is ordinarily known as the "sacrum." To this, in turn, the iliac bones are anchylosed along their whole length, giving perfect immobility to this region of the spine and to the pelvis.

The coccygeal or caudal vertebræ vary in number from eight to ten, and are movable upon one another. In reality, however, the number of caudal vertebræ is much greater than the above, since some of the vertebræ of the anchylosed "sacrum" properly fall to be counted in this region, and the "ploughshare-bone" consists of more than one vertebra. The most noticeable feature about this part of the spinal column is what is known as the "ploughshare-bone." This is the last joint of the tail, and is a long, slender, ploughshare-shaped bone, destitute of lateral processes, and without any medullary canal (fig. 325, B). In reality it consists of two or more of the caudal vertebræ, completely anchylosed, and fused into a single mass. It is usually set on to the extremity of the spine at an angle more or less nearly perpendicular to the axis of the body; and it affords a firm basis for the support of the great quill-feathers of the tail ("rectrices"). It also supports the coccygeal oil-gland, and can be raised at pleasure, so as to meet the bill, when the operation of preening is in progress. In the Cursorial Birds, which do not fly, the terminal joint of the tail is not ploughshare-shaped. In the extraordinary Mesozoic bird, the *Archæopteryx macrura*, there is no ploughshare-bone, and the tail consists of twenty separate vertebræ, all distinct from one another, and each carrying a pair of quill-feathers, one on each side (fig. 351). As the vertebræ of the ploughshare-bone are distinct from one another in the embryos of existing birds, the tail of the *Archæopteryx* is to be regarded as a case of the permanent retention in the adult of an embryonic character. In the increased number of caudal vertebræ, however, and in some other characters, the tail of the *Archæopteryx* makes a decided approach to the true Reptiles.

The various bones which compose the *skull* of Birds are amalgamated in the adult so as to form a single piece, and the sutures even are obliterated, the lower and upper jaws alone remaining movable. The occipital bone carries a single occipital condyle only, and this is hemispherical or nearly globular in shape. The nasal bones are short, so that the nostrils (except in *Apteryx*) are placed far backwards. The "beak" (fig. 321), which forms such a conspicuous feature in all birds, consists of an upper and lower half, or a "superior" and "inferior mandible." The upper mandible is composed principally of the greatly elongated and coalescent intermaxillary bones, which give off long "frontal processes," and are flanked by the comparatively small superior maxillæ. The inferior mandible is primitively composed of twelve pieces, six on each side; but in the adult these are all indistinguishably amalgamated with one another, and the lower jaw forms a single piece. As in the Reptiles, the lower jaw articulates with the skull, not directly, but through the intervention of a distinct bone—the quadrate bone—which always remains permanently movable, and is never anchylosed with the skull. In no living bird are teeth ever developed in either jaw, but both mandibles are encased in horn, forming the beak, and the margins of the bill are sometimes serrated. The quadrate bone is movable, and has articulated to it in front the slender rod-like "jugal" bone or "quadrato-jugal," which is, in turn, immovably united with the slender maxilla on each side. When the mandible is depressed, the quadrate bone is thrust forward, and the rod formed by the coalescent jugal and maxilla on each side elevates the upper half of the beak, which is usually articulated in a more or less movable manner with the front of the skull. The Parrots possess this movable articulation of the upper jaw with the skull in its greatest perfection; but it exists in a less complete form in most birds. The maxillæ of birds, as before remarked, are comparatively slender bones; but they send in-

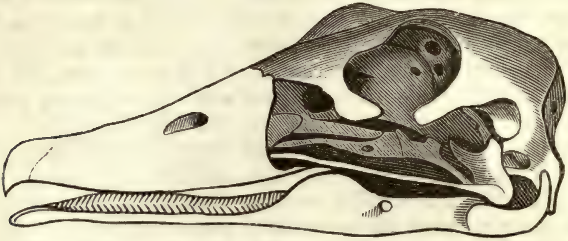

Fig. 321.—Skull of Spur-winged Goose (*Plectropterus Gambensis*).

wards extensively developed horizontal processes ("maxillo-palatine processes"), which form a large portion of the hard palate. The extent, however, to which these processes are developed varies much in different birds, and on these variations, combined with the structure of the vomer, Prof. Huxley has proposed to found the following divisions of the Carinate Birds:—

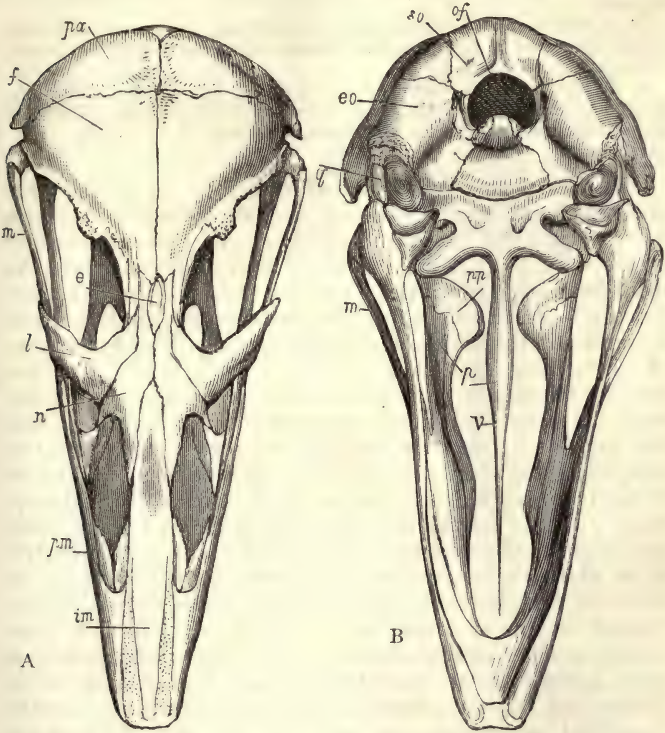

Fig. 322.—Skull of young Ostrich, viewed from above (A), and from below (B). (After Owen.) *of* Occipital foramen; *so* Supra-occipital: *eo* Exoccipital; *q* Quadrate; *pa* Parietal; *pp* Pterygoid process; *f* Frontal; *e* Ethmoid; *n* Nasal; *pm* Maxillary process of præmaxilla; *m* Malar or jugal bone; *im* Præmaxilla; *p* Palatine bone; *v* Vomer; *l* Lachrymal bone. The skull being that of a young bird, the sutures are not yet obliterated.

1. *Desmognathæ.*—Maxillæ sending inwards largely developed maxillo-palatine processes, which unite with one another to form a bony roof to the palate. The vomer truncated in front, small or obsolete. *Ex.* Birds of

Prey, Parrots, Cuckoos, Kingfishers, Trogons, Anserine birds, Storks, Cormorants.

2. *Schizognathæ.*—Maxillo-palatine processes of the maxillæ separated by a wider or narrower cleft. Vomer long and pointed in front, narrow behind. *Ex.* Plovers, Gulls, Penguins, Cranes, Fowls, Sand-grouse, Pigeons.

3. *Ægithognathæ.* — Maxillo-palatine processes separated by a cleft. Vomer truncated in front, narrow behind. *Ex.* Perching Birds, Swifts, Woodpeckers.

4. *Dromæognathæ.* — Vomer broad behind, interposing between the pterygoids, the palatine bones, and the basi-sphenoid rostrum. This division includes only the Tinamous (*Tinamomorphæ*).

The thoracic cavity is bounded behind by the dorsal vertebræ, which are usually, as before said, anchylosed to one another to a greater or less extent. Laterally, the thorax is bounded by the ribs, which vary in number from six to ten pairs. In most birds, each rib carries a peculiar process—the "uncinate process"—which arises from its posterior margin, is directed upwards and backwards, and passes over the rib next in succession behind, where it is bound down by ligament. The first and last dorsal ribs carry no uncinate processes, and in some cases the processes continue throughout life as separate pieces (fig. 323, B). Anteriorly, the ribs articulate with a series of straight bones, which are called the "sternal ribs," and which in reality are to be looked upon as the ossified "costal cartilages." These sternal ribs (fig. 323, B) are in turn movably articulated to the sternum in front, and "they are the centres upon which the respiratory movements hinge" (Owen). In front the thoracic cavity is completed by an enormously-expanded sternum or breast-bone, which in some birds of great powers of flight extends over the abdominal cavity as well, in some cases even reaching the pelvis. The sternum of all birds which fly, is characterised by the presence of a greatly-developed median ridge or keel (fig. 323, A), to which are attached the great pectoral muscles which move the wings. As a general rule, the size of this sternal crest allows a very tolerable estimate to be formed of the flying powers of the bird to which it may have belonged; and in the Ostriches and other birds which do not fly, there is no sternal keel. At its anterior angles the sternum exhibits two pits for the attachment of the coracoid bones.

The scapular or pectoral arch consists of the shoulder-blade or scapula, the collar-bone or clavicle, and the coracoid bone, on each side. The scapula, as a rule (fig. 323, A, *s s*), is a simple elongated bone, not flattened out into a broad plate, and carrying no transverse ridge, or spinous process. Only a portion of the glenoid cavity for the articulation with the head of the humerus is formed by the scapula, the remainder being formed by the coracoid. The coracoid bones (fig. 323, A, *k k*) correspond with the coracoid processes of man; but in birds they are distinct bones, and are not anchylosed with the scapula. The coracoid bone on each side is always the strongest of the bones forming the scapular arch. Superiorly it articulates with the clavicle and scapula, and forms part of the glenoid cavity for the humerus. Inferiorly each coracoid bone articulates with the upper angle of the sternum. The position of the coracoids is more or less nearly vertical, so that they form fixed points for the action of the wings in their downward stroke. The clavicles (fig. 323, A, *c*) are rarely rudimentary or absent, and are in some few cases separate bones. In the great majority, however, of birds, the clavicles are anchylosed together at their anterior extremities, so as to form a single bone, somewhat V-shaped, popularly known as the "merry-thought," and technically called the "furculum" ("fourchette" of the French). The outer extremities of the furculum articulate with the scapula and coracoid; and the anchylosed

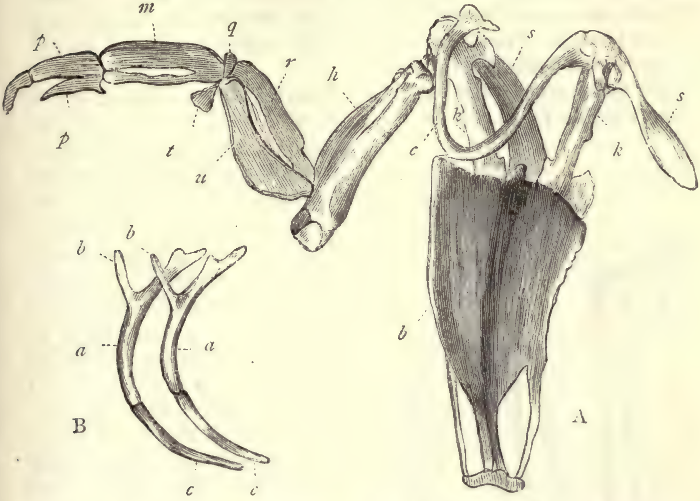

Fig. 323.—A, Breast-bone, shoulder-girdle, and fore-limb of Penguin (after Owen): *b* Sternum, with the sternal keel; *s s* Scapulæ; *k k* Coracoid bones; *c* Furculum or merry-thought, composed of the united clavicles; *h* Humerus: *u* Ulna; *r* Radius; *t* Thumb; *m* Metacarpus; *p p* Phalanges of the fingers. B, Ribs of the Golden Eagle: *a a* Ribs giving off (*b b*) uncinate processes; *c c* Sternal ribs.

angle is commonly united by ligament to the top of the sternum. The function of the clavicular or furcular arch is "to oppose the forces which tend to press the humeri inwards towards the mesial plane, during the downward stroke of the wing" (Owen). Consequently the clavicles are stronger, and their angle of union is more open, in proportion to the powers of flight possessed by each bird. The furculum is rudimentary in the Ostrich, Emeu, and Cassowary, and it is absent in the Apteryx and some Parrots.

We have next to consider the structure of the bones which compose the fore-limb or "wing" of the bird; and as this organ is the one which chiefly conditions the peculiar life of the bird, it is in it that we find some of the most characteristic points of structure in the whole skeleton. Though considerably modified to suit its function as an organ of aerial progression, the wing of the bird is readily seen to be homologous with the arm of a man or the fore-limb of a Mammal (fig. 323, A, and fig. 324). The upper arm (*brachium*) is supported by a single bone, the humerus, which is short and strong, and articulates above with the articular cavity formed partly by the scapula and partly by the coracoid (fig. 324, *h*). The humerus is succeeded distally by the fore-arm (*antibrachium*), constituted by the normal two bones, the radius and ulna (fig. 324, *r*, *u*), of which the radius is the smaller and more slender, and the ulna the larger and stronger. The ulna and radius are followed inferiorly by the bones of the wrist or carpus; but these are reduced in number to *two* small bones, one radial and one ulnar, "so wedged in between the antibrachium and metacarpus as to limit the motions of the hand to those of abduction and adduction necessary for the folding up and expansion of the wing; the hand is thus fixed in a

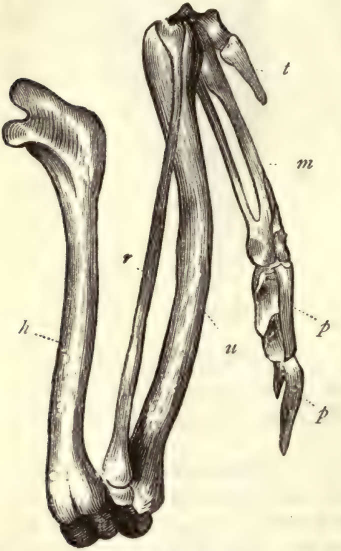

Fig. 324.—Fore-limb of the Jer-falcon. *h* Humerus; *r* Radius; *u* Ulna; *t* "Thumb;" *m* Metacarpals, anchylosed at their extremities; *p p* Phalanges of fingers.

state of pronation; all power of flexion, extension, or of rotation, is removed from the wrist-joint, so that the wing strikes firmly, and with the full force of the contraction of the depressor muscles, upon the resisting air" (Owen). One other bone of the normal carpus (namely, the "os magnum") is present, but this is anchylosed with one of the metacarpals. There are thus really *three* carpal bones, though only two appear to be present. (According to Morse, there is a *fourth* carpal, which early anchyloses with the base of the metacarpal of the middle finger.) The carpus is followed by the metacarpus, the condition of which agrees with that of the carpal bones. The two outermost of the normal five metacarpals are absent, and the remaining three are anchylosed—together with the os magnum—so as to form a single bone (fig. 324, *m*). This bone, however, appears externally as if formed of *two* metacarpals united to one another at their extremities, but free in their median portion. The metacarpal bone which corresponds to the radius is always the larger of the two (as being really composed of two metacarpals), and it carries the digit which has the greatest number of phalanges. This digit corresponds with the "index" finger, and it is composed of two, or sometimes three, phalanges (fig. 324, *p*). At the proximal end of this metacarpal, at its outer side, there is generally attached a single phalanx, constituting the so-called "thumb" (fig. 324, *t*), which carries the "bastard-wing," and is sometimes furnished with a claw. The digit which is attached to the ulnar metacarpal corresponds to the middle finger, and never consists of more than a single phalanx (fig. 324). In the Apteryx and the Cassowary there is only one complete digit to the hand.

As regards the structure of the posterior extremity or hind-limb, the pieces which compose the innominate bones (namely, the ilium, ischium, and pubes) are always anchylosed with one another; and the two innominate bones are also always anchylosed, by the medium of the greatly-elongated ilia, with the sacral region of the spine. In no living bird, however, with the single exception of the Ostrich, are the innominate bones united in the middle line in front by a symphysis pubis. The stability of the pelvic arch, necessary in animals which support the weight of the body on the hind-limbs alone, is amply secured in all ordinary cases by the anchylosis of the ilia with the sacrum.

As in the higher Vertebrates, the lower limb (fig. 325, A) consists of a femur, a tibia and fibula, a tarsus, metatarsus, and phalanges; but some of these parts are considerably obscured by anchylosis. The femur or thigh-bone (fig. 325, A, *f*) is generally very short, comparatively speaking. The chief bone of the leg is the tibia (*t*), to which a thin and tapering fibula (*r*) is anchylosed. The upper end of the fibula, however, articulates with the external condyle of the femur. The ankle-joint is placed, as in Reptiles, between the proximal and distal portions of the tarsus. The proximal portion of the tarsus, consisting of two bones, representing the astragalus and calcaneum or the former only, is undistinguishably amalgamated with the lower end of the tibia. The distal portion of the tarsus is anchylosed with the second, third, and fourth metatarsals to constitute the most characteristic bone in the leg of the Bird—the "tarso-metatarsus" (*m*). In most of the long-legged birds, such as the Waders, the disproportionate length of the leg is given by an extraordinary elongation of the tarso-metatarsus.

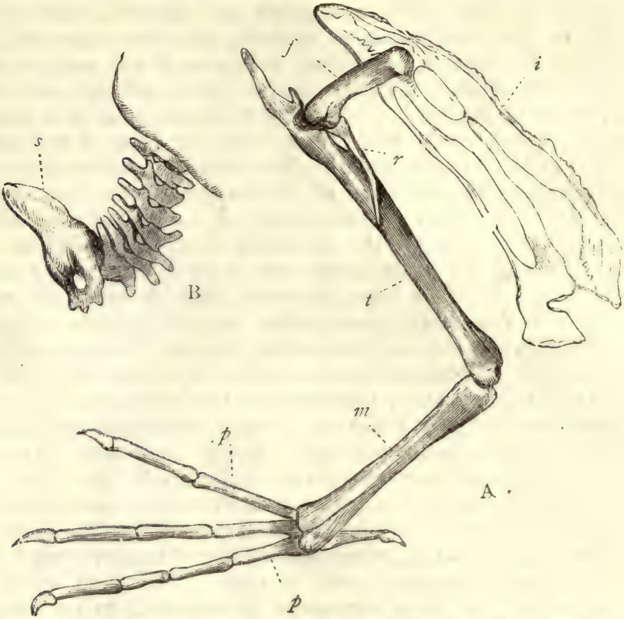

Fig. 325.—A, Hind-limb of the Loon (*Colymbus glacialis*)—after Owen: *i* Innominate bone; *f* Thigh-bone or femur; *t* Tibia, with the proximal portion of the tarsus anchylosed to its lower end; *r* Fibula; *m* Tarso-metatarsus, consisting of the distal portion of the tarsus anchylosed with the metatarsus; *p p* Phalanges of the toes. B, Tail of the Golden Eagle; *s* Ploughshare-bone, carrying the great tail-feathers.

The tarso-metatarsus is followed inferiorly by the digits of the foot. In most birds the foot consists of three toes directed forwards and one backwards—four toes in all. In no wild bird are there *more* than four toes, but often there are only three, and in the Ostrich the number is reduced to two. In all birds which have three anterior and one posterior toe, it is the posterior thumb or *hallux* (that is to say, the innermost digit of the hind-limb) which is directed backwards; and it invariably consists of *two* phalanges only, its metatarsal being incomplete and united as a rule to the tarso-metatarsus by ligament only. The most internal of the three anterior toes (the "index") consists of three phalanges; the next ("middle") has four phalanges; and the outermost toe ("annularis") is made up of five phalanges (fig. 325, A). This increase in an arithmetical ratio of the phalanges of the toes, in proceeding from the inner to the outer side of the foot, obtains in almost all birds, and enables us readily to detect which digit is suppressed, when the normal four are not all present. Variations of different kinds exist, however, in the number and disposition of the toes. In many birds—such as the Parrots—the outermost toe is turned backwards, so that there are two toes in front and two behind, whilst in the Trogons the inner toe is turned back with the hallux, and the outermost toe is turned forwards. In others, again, the outer toe is normally directed forwards, but can be turned backwards at the will of the animal. In the Swifts, on the other hand, all four toes are present, but they are all turned forwards. In many cases—especially amongst the Natatorial birds—the hallux is wholly wanting, or is rudimentary. In the Emeu, Cassowary, Bustards, and other genera, the hallux is invariably absent, and the foot is three-toed. In the Ostrich both the hallux and the next toe ("index") are wanting, and the foot consists simply of two toes, these being the third and fourth digits. The toes are mechanically flexed during the sleep of most birds by the action of a special muscle which runs from the pubis outside the knee to join one of the flexors of the toes (the flexor digitorum perforatus), and which is therefore put on the stretch whenever the leg is bent upon the thigh.

The *digestive system* of birds comprises the beak, tongue, gullet, stomach, intestines, and cloaca. Teeth are invariably wanting in living birds, and the jaws are encased in horn, constituting the bill. Dental papillæ, sometimes covered with a cap of dentine, have, however, been observed in the embryos of some Parrots. In the extinct *Odontopteryx*, moreover, the osseous substance of the jaws is prolonged into tooth-like processes of two sizes; and in the *Odontornithes* of the Cretaceous period the jaws are furnished with true teeth implanted in distinct sockets. The form of the bill varies enormously in different birds, and it is employed for holding and tearing the prey, for prehensile purposes, for climbing, and in some birds as an organ of touch. In these last-mentioned cases the bill is more or less soft, and is supplied with filaments of the fifth nerve. In many birds, too, in which the bill is not soft, the base of the upper mandible is surrounded by a circle of naked skin, constituting what is called the "cere," and this, no doubt, serves also as a tactile organ.

The tongue of birds can hardly be looked upon as an organ of taste, since it is generally cased in horn like the mandibles. It is, in fact, principally employed as an organ of prehension; but in some cases—as in the Parrots—it is soft and fleshy, and then, doubtless, is to some extent connected with the sense of taste. It is essentially composed of a prolongation of the hyoid bone (the glosso-hyal), which is sheathed in horn, and is variously serrated or fringed.

Salivary glands are invariably present, but they are rarely of large size (they are very large in the Woodpeckers and Swifts), and they have often a very simple structure.

In accordance with the structure of the neck, the gullet in birds is usually of great length, and it is generally very dilatable. In the carnivorous, or Raptorial, and in the granivorous birds, the gullet (fig. 326, *o*) is dilated into a pouch, which is situated at the lower part of the neck, just in front of the merry-thought. This is what is known as the "crop" or "ingluvies" (*c*), and it may be either a mere dilatation of the tube of the gullet, or it may be a single or double pouch. The food is detained in the crop for a longer or shorter time, according to its nature, before it is subjected to the action of the proper digestive organs. The œsophagus, after leaving the crop, shortly opens into a second cavity, which is known as the "proventriculus" or "ventriculus succenturiatus" (*p*). This is the true digestive cavity, and its mucous membrane is richly supplied with gastric follicles which secrete the gastric juice. The proventriculus, however, corresponds, not with the whole stomach of the Mammals, but only with its cardiac portion; and it opens into a second muscular cavity, which corresponds to the pyloric division of the Mammalian stomach. The gizzard (*g*) is situated below the liver, and forms in all birds an elongated sac, having two apertures above, of which one conducts into the duodenum, or commencement of the small intestine, whilst the other communicates with the proventriculus. The two chief forms of gizzard are exhibited respectively by the Raptorial birds, which feed on easily-digested animal food, and the *Rasores* and some of the *Natatores*, which feed on hardly-digested grains. In the birds of Rapine the gizzard scarcely deserves the name, being, as a rule, nothing more than a wide membranous cavity with thin walls. In the granivorous birds, whose hard food requires crushing, the gizzard is enormously developed; its lining coat is formed of a thick, horny epithelium, and its walls are extremely thick and muscular. This constitutes a grinding apparatus, like the stones of a mill; whilst the "crop" or œsophageal dilatation may be compared to the "hopper" of a mill, since it supplies to the gizzard "small successive quantities of food as it is wanted" (Owen). Supplementing the action of the muscular walls of the gizzard, and acting in the place of teeth, are the small stones or pebbles, which, as is so well known, so many of the granivorous birds are in the habit of swallowing with their food, or at other times. In fact, there can be no doubt but that the gravel and pebbles swallowed by these birds are absolutely essential to existence, since the

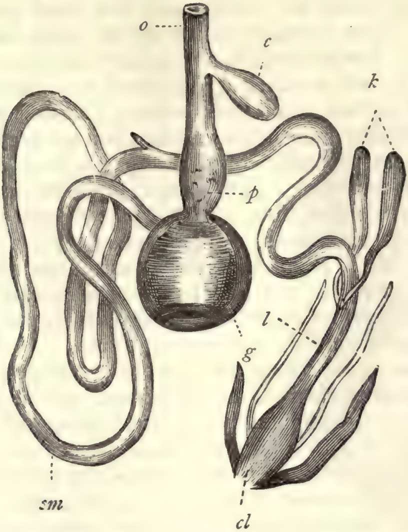

Fig. 326.—Digestive System of the common Fowl (after Owen). *o* Gullet; *c* Crop; *p* Proventriculus; *g* Gizzard; *sm* Small intestine; *k* Intestinal cæca; *l* Large intestine; *cl* Cloaca.

gizzard, without this assistance, is unable properly to triturate the food.

The intestinal canal extends from the gizzard to the cloaca, and is, comparatively speaking, short. The secretions of the liver and pancreas are poured into the small intestine as in Mammals. The commencement of the large intestine is almost always furnished with two long "cæca" or blind tubes, the length of which varies a good deal in different birds (fig. 326, *k*). They are sometimes wanting (Parrots, &c.), or there may be only one; and their exact function is uncertain; though they are most probably connected partly with digestion and partly with excretion. The large intestine is always very short—seldom more than a tenth part of the length of the body—and it terminates in the "cloaca" (fig. 326, *cl*). This is a cavity which in all birds receives the termination of the rectum, the ducts of the generative organs, and the ureters; and serves, therefore, for the expulsion of the fæces, the generative products, and the urinary secretion.

Respiration is effected in Birds more completely and actively than in any other class of the *Vertebrata*, and as the result of this, their average temperature is also higher. This extensive development of the respiratory process is conditioned by the the fact that, in addition to true lungs, air is admitted into a greater or less number of the bones, and into a number of cavities—the so-called air-receptacles—which are distributed through various parts of the body, and which are present in all birds except the *Apteryx*. By this extensive penetration of air into various parts of the body, the aeration of the blood is effected not only in the lungs, but also over a greater or less extent of the systemic circulation as well; and hence in Birds this process attains its highest perfection. The cavities of the thorax and abdomen are not separated from one another by a complete partition, the diaphragm being mostly only present in a rudimentary form. The lungs are two in number, of a bright-red colour, and spongy texture. They are confined to the back of the thorax, extending along each side of the spine, from the second dorsal vertebra to the kidney. They differ from the lungs of the Mammals in not being freely suspended in a pleural membrane. The pleura, on the other hand, is reflected only over the anterior surface of the lungs. The bronchi, or primary divisions of the windpipe (fig. 327), diminish in size as they pass through the lung, by giving off branches, which, in turn, give off the true air-vesicles of the lung. When the bronchial tubes reach the surface of the lung, they open, by a series of distinct apertures, into a series of "air-sacs." These are a series of membranous sacs formed by the continuation of the lining membrane of the bronchi, and supported by reflections of the serous membrane of the thoracico-abdominal cavity. There are nine proper air-sacs—two abdominal (the only ones present in some birds, such as the Penguin), two in the hinder part of the thorax, two in the front part of the thorax, two on the sides of the neck, and one between the branches of the furculum. The air-cells not only greatly reduce the specific gravity of birds, and thus fit them for an aerial life, but also assist in the mechanical work of respiration, and must also greatly promote the aeration of the blood.

In connection with the air-receptacles, and as an extension of them, is a series of cavities occupying the interior of a greater or less number of the bones, and also containing air. In young birds these air-cavities do not exist, and the bones are filled with marrow, as in the Mammals. The extent also to which the bones are "pneumatic" varies greatly in different birds. In the Penguin — which does not fly — all the bones contain marrow, and there are no air-cavities. In the large Running birds (*Cursores*), such as the Ostrich, the bones of the leg, pelvis, spine, ribs, skull, and sternum, are pneumatic; but the bones of the wings, with the exception of the scapular arch, are without air-cavities, and permanently retain their marrow. All birds which fly, with the singular exception of the Woodcock, have air admitted to the humerus. In the Pelican and Gannet, all the bones of the skeleton, except the phalanges of the toes, are penetrated by air; and in the Hornbill even these are pneumatic. The functions discharged by the air-cavities of the bones appear to be much the same as those of the air-receptacles—namely, that of diminishing the specific gravity of the body and subserving the aeration of the blood.

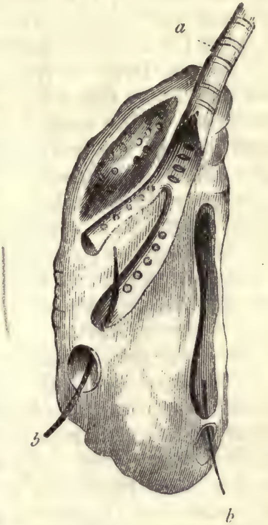

Fig. 327.—Lung of Goose (after Owen). *a* Main bronchus dividing into secondary branches as it enters the lung, these giving off smaller branches, the openings of which are seen on the back of the bronchial tubes: *b b* Bristles passed from the bronchi through the apertures on the surface of the lung by which the bronchi communicate with the air-receptacles.

The *heart* in all Birds consists of four chambers, two auricles and two ventricles. The right auricle and ventricle, constituting the right side of the heart, are wholly concerned with the pulmonary circulation; the left auricle and ventricle, forming the left side of the heart, are altogether occupied with the systemic circulation; and no communication normally exists in adult life between the two sides of the heart. In all essential details, both as regards the structure of the heart itself and the course taken by the circulating fluid, Birds agree with Mammals. The venous blood—namely, that which has circulated through the body—is returned by the venæ cavæ to the right auricle, whence it is poured into the right ventricle. The right ventricle propels it through the pulmonary artery to the lungs, where it is aerated, and becomes arterial. It is then sent back by the pulmonary veins to the left auricle, whence it is driven into the left ventricle. Finally, the left ventricle propels the aerated blood to all parts of the body through the great systemic aorta.

The chief difference between Birds and Reptiles as regards the course of circulation is, that in the Birds the two sides of the heart are completely separated from one another, the blood sent to the lungs being exclusively venous, whereas that which is sent to the body is exclusively arterial. In Reptiles, on the other hand, the pulmonary and systemic circulations are connected together either in, or in the immediate neighbourhood of, the heart; so that mixed venous and arterial blood is propelled both through the lungs and through every part of the body.

In accordance with their extended respiration and high muscular activity, the complete separation of the greater and lesser circulations, and the perfect structure of the heart, Birds maintain a higher average temperature than is the case with any other class of the *Vertebrata*. This result is also to a considerable extent conditioned by the non-conducting nature of the combined down and feathers which form the integumentary covering of Birds.

The *urinary organs* of Birds consist of two elongated kidneys, and two ureters, but there is no urinary bladder. The ureters open into the cloaca, or into a small urogenital sac which communicates with the cloaca.

As regards the *reproductive organs*, the males have two testes placed above the upper extremities of the kidneys, and their efferent ducts (*vasa deferentia*) open into the cloaca alongside of the ureters. A male organ (*penis*) may or may not be present, but there is no perfect urethra. The female bird is provided with only one ovary and oviduct — that of the left side — the corresponding organs of the right side being rudimentary or absent. The oviduct is very long and tortuous, and the egg, during its passage through it, receives the albuminous covering which serves for the nutrition of the embryo, and which is known as the "white" of the egg. The lower portion of the oviduct is dilated, and the egg receives here the calcareous covering which constitutes the "shell." Finally, the oviduct debouches into the cloaca, into which the egg, when ready, is expelled. The further development of the chick is secured by the process of "incubation" or brooding, for which birds are peculiarly adapted, in consequence of the high temperature of their bodies.

The development of the ovum belongs to physiology, and does not concern us here. It is sufficient to notice the means by which the chick is ultimately enabled to escape from the egg. When development has reached a stage at which external life is possible, it is of course necessary for the chick to be liberated from the egg, the shell of which is often extremely hard and resistant. To this end the young bird is provided with a little calcareous knob on the point of the upper mandible, and by means of this it chips out an aperture through the shell, at its blunt end. Having effected its purpose, this temporary appendage then disappears, without leaving a trace behind.

The state of the young upon exclusion from the egg is very different in different cases, and in accordance with this, Birds have been divided into the two sections of the *Autophagi* or *Aves præcoces*, and the *Heterophagi* or *Aves altrices.* In the *Autophagi* the young bird is able to run about and help itself from the moment of liberation from the egg. In the *Heterophagi* the young are born in a blind and naked state, unable to feed themselves, or even to maintain unassisted the necessary vital heat. In these birds, therefore, the young require to be brooded over and fed by the parents for a longer or shorter period after exclusion from the egg.

As regards their *nervous system*, the brain of Birds is relatively larger, especially as regards the size of the cerebrum proper, than the brain of Reptiles, but the chief mass of the latter consists of the *corpora striata*, and it does not cover the cerebellum. The cerebellum is less developed than in Mammals, the lateral lobes and Pons Varolii being rudimentary. The corpus callosum is absent, and the surface of the cerebral hemispheres is devoid of convolutions.

As regards the *organs of the senses*, the eyes are always well developed, and in no bird are they ever rudimentary or absent. The chief peculiarity of the eye is that the cornea forms a segment of a much smaller sphere than does the eyeball proper, so that the anterior part of the eye is obtusely conical, whilst the posterior portion is spheroidal. Another peculiarity is that the form of the eye is maintained by a ring of from thirteen to twenty bony plates, which are placed in the anterior portion of the sclerotic coat. Eyelashes are almost universally absent; but in addition to the ordinary upper and lower eyelids, Birds possess a third membranous eyelid—the "membrana nictitans"—which is sometimes pearly-white, sometimes more or less transparent.* This third eyelid is placed on the inner side of the eye, and possesses a special muscular apparatus, by which it can be drawn over the anterior surface of the eye, like a curtain, moderating the intensity of the light. As to the organ of hearing, most birds possess no external ear or concha, by which sounds can be collected and transmitted to the internal ear. In some birds, however, as in the Ostrich and Bustard, the external meatus auditorius is surrounded by a circle of feathers, which can be raised and depressed at will. The Nocturnal Birds, also, especially Owls, have the external meatus auditorius protected by a musculo-membranous valve, which foreshadows the cartilaginous concha of the majority of Mammals. The external nostrils in Birds are usually placed on the sides of the upper mandible, near its base, in the form of simple perforations, which sometimes communicate from side to side by the deficiency of the septum narium. In the singular *Apteryx* of New Zealand, the nostrils are placed at the extreme end or tip of the elongated upper mandible. Sometimes the nostrils are defended by bristles, and sometimes by a scale (*Rasores*). Taste must be absent, or almost absent, in the great majority of birds, the tongue being nothing more than a horny sheath surrounding a process of the hyoid bone, and serving for deglutition or to seize the prey. In the Parrots, however, the tongue is thick and fleshy, and some perception of taste may be present. Touch or tactile sensibility, too, as already remarked, is very poorly developed in Birds. The body is entirely, or almost entirely, covered with feathers; the anterior limbs are converted into wings, and rendered thereby useless as organs of touch; and the posterior limbs are covered with horny scales or feathers. The bill, certainly, officiates as an organ of touch, but it cannot possess any acute sensibility, as in most birds it is encased in a rigid horny sheath. In some birds, however, such as the common Duck, the texture of the bill is moderately soft, and it is richly supplied with filaments of the fifth nerve; so that in these cases the bill doubtless constitutes a tolerably efficient tactile organ. The "cere," too, or the fleshy scale found at the base of the bill in some birds, is in all probability also used as a tactile organ.

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* The membrana nictitans is simply a fold of the conjunctiva on the inner side of the eye. It occurs in some Fishes (*e.g.*, some Sharks), in some Reptiles and Amphibians, in Birds, in Monotremes and Marsupials, and in some of the higher Mammals. In Man, however, in Monkeys, and in most of the higher Mammals, it is rudimentary, and constitutes the so-called "plica semilunaris."

The last anatomical peculiarity of Birds which requires notice is the peculiar apparatus known as the "inferior larynx," or "syrinx," by which the song of the singing birds is conditioned. "The air-passages of birds commence by a simple *superior larynx*, from which a long *trachea* extends to the anterior aperture of the thorax, where it divides into the two *bronchi*, one for each lung. At the place of its division, there exists in most birds a complicated mechanism of bones and cartilages, moved by appropriate muscles, and constituting the true organ of voice; this part is termed the *inferior larynx*" (Owen). The inferior larynx may be developed from the trachea only, before the division of this tube into the bronchi; or, it may be developed wholly from the bronchi; or, lastly, and more commonly, it may be developed at the junction of the trachea and bronchi and out of both. The structure of the vocal apparatus is extremely complicated, and there is no necessity for entering upon it here. It is to be remembered, however, that those modifications of the voice which constitute the song of birds, are produced in a special and complex cavity placed at, or near, the point where the trachea divides into the two bronchi, and *not* in a true larynx situated at the summit of the windpipe. The syrinx is wanting in a few birds (*e.g.*, the *Ratitæ*). Lastly, the trachea of birds is always of considerable proportionate length, and it is often twisted or dilated at intervals, this structure, doubtless, having something to do with the production of vocal sounds.

Before passing on to the consideration of the divisions of Birds, a few words may be said as to the *migration* of birds. In temperate and cold climates comparatively few birds remain constantly in the same region in which they were hatched. Those which do so remain, are called "permanent birds" (*aves manentes*). Other birds, such as the Woodpeckers, wander about from place to place, without having any fixed direction. These are called "wandering birds" (*aves erraticæ*), and their irregular movements are chiefly conditioned by the scarcity or abundance of food in any particular locality. Other birds, however, at certain seasons of the year undertake long journeys, usually uniting for this purpose into large flocks. These birds—such as the swallows, for instance—are properly called "migratory birds" (*aves migratoriæ*). The movements of these birds are conditioned by the necessity of having a certain mean temperature, and consequently they leave the cold regions at the approach of winter, and return again for the warmer season.

DISTRIBUTION OF BIRDS IN TIME.—As regards the geological distribution of Birds, there are many reasons why we should be cautious in reasoning upon merely negative evidence, and more than ordinarily careful not to infer the non-existence of birds during any particular geological epoch, simply because we can find no positive evidence for their presence. As Sir Charles Lyell has well remarked, "the powers of flight possessed by most birds would insure them against perishing by numerous casualties to which quadrupeds are exposed during floods;" and "if they chance to be drowned, or to die when swimming on water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary deposits," since, from the lightness of the bones, the carcass would remain long afloat, and would be liable to be devoured by predaceous animals. As, with a few utterly trivial exceptions, all the deposits in which fossils are found have been laid down in water, and more especially as they are for the most part marine, these considerations put forward by Sir Charles Lyell afford obvious ground against the anticipation that the remains of Birds should be either of frequent occurrence or of a perfect character in any of the fossiliferous rocks. In accordance with these considerations, as a matter of fact, most of the known remains of birds are either fragmentary or belong to forms which were organised to live a terrestrial life, and were not adapted for flight.

The earliest remains which have been generally referred to birds are in the form of footprints (fig. 328) impressed upon certain sandstones in the valley of the Connecticut River in the United States. These sandstones are almost certainly Triassic; and if the ornithic character of these footprints be admitted, then Birds date their existence from the commencement of the Mesozoic period, and, for anything we know to the contrary, may have existed during the Palæozoic epoch. In the fact that these footprints are three-toed, and are certainly the tracks of bipedal animals, we have strong evidence that they were produced by birds. On the other hand, it is certain that some of the Deinosaurian Reptiles of the Triassic period walked on their hind-legs only, and it is highly probable that *they* were the real authors of the prints in question. If truly ornithic, we must admit the existence in the Triassic period of a considerable number of kinds of Birds, some of which must have been of colossal dimensions, but this question does not admit of final settlement at present.

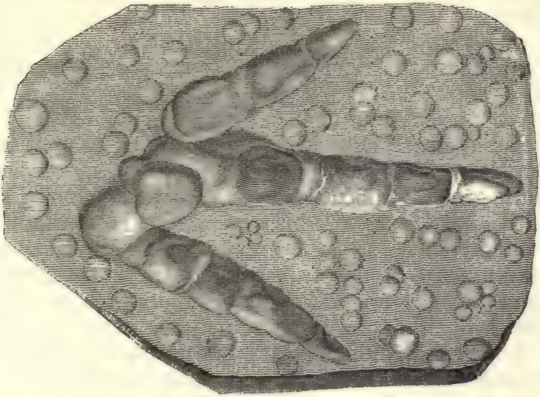

Fig. 328.—Footprint supposed to belong to a Bird. Triassic Sandstones of Connecticut.

The first unmistakable remains of a bird have been found in the Solenhofen Slates of Bavaria, of the age of the Upper Oolites. A single unique specimen, consisting of bones and feathers, but unfortunately without the skull, is all that has until recently been discovered; and it has been named the *Archæopteryx macrura*. The characters of this singular and aberrant bird, which alone constitutes the order *Saururæ*, will be given in treating of the order.

In the Cretaceous rocks, not only do we find the remains of Birds of the type now existing, but we meet with the extraordinary "Toothed Birds" (*Odontornithes*), which seem not to have survived this period, and which will be spoken of in greater detail later on. Lastly, almost all the existing orders of Birds are represented by the time we reach the middle of the Tertiary period, and the distribution and characters of the more important fossil forms will be treated of in discussing the several orders in question.

CHAPTER LXIV.

DIVISIONS OF BIRDS.

1. General Divisions of Aves. 2. Cursores.

Owing to the extreme compactness and homogeneity of the entire class *Aves*, conditioned mainly by their adaptation to an aerial mode of life, the subject of their classification has been one of the greatest difficulties of the systematic zoologist.

By Professor Huxley the birds are divided into the following three orders :—

1. Saururæ.—In this order the caudal vertebræ are numerous, and there is no ploughshare-bone. The tail is longer than the body, and the metacarpal bones are not anchylosed together. This order includes only the single extinct bird the *Archæopteryx macrura*, in which the long lizard-like tail is only the most striking of several abnormalities.

2. Ratitæ. — This order comprises the Running birds, which cannot fly, such as the Ostriches, Emeus, and Cassowaries. It is characterised by the fact that the sternum has no median ridge or keel for the attachment of the great pectoral muscles. The sternum is therefore raft-like (from the Lat. *rates*, a raft), hence the name of the order.

3. Carinatæ.—This comprises all the living Flying birds, and is characterised by the fact that the sternum is furnished with a prominent median ridge or keel (*carina*); hence the name of the order. The numerous subdivisions of this order are mainly founded upon the structure of the palate.

As regards the above primary divisions of Birds, there can be no doubt as to their being very natural sections. A fourth division, of equal rank, must now be added for the extinct *Odontornithes*, and all four divisions may be best considered as *sub-classes*, and not as mere *orders*.* No difficulty, also, is to be found in subdividing the *Ratitæ*, *Saururæ*, and *Odontornithes*; but there is the greatest difficulty in establishing natural subdivisions amongst the great sub-class of the *Carinatæ*, since this includes by far the greater number of known birds. The classification of this group proposed by Professor Huxley (like that of Mr Garrod), descending, as it does, to a great number of secondary groups, is not only too complicated to be available for the general student, and therefore to be useful in a work of the present nature; but it is intended primarily for the anatomist, and not for the systematic zoologist. The latter requires a classification based upon *all* the characters, internal and external; whereas the morphological method of arrangement selects simply single structures in the anatomy of the bird, and fixes its place by means of these. Thus, Prof. Huxley founds his classification of the *Carinatæ* upon the structure of the bony palate. This method of classification, however, though of the greatest use to the comparative anatomist, cannot be made to coincide with any purely zoological mode of arrangement. It has, therefore, seemed preferable for the purpose of the present work to adhere, with some modifications, to the old classification of Birds, which is to be found, in one form or another, in almost all the standard works on ornithology. In using, however, the six old orders of this system, with their familiar and long current names, the student must remember that they bear very unequal values. Some of them—such as the *Natatores*, *Grallatores*, *Rasores*, and *Raptores*—are essentially natural groups, and cannot be seriously mutilated in any system of classification. The order *Insessores* is also, in the main, a natural one, though it includes groups which can only be artificially connected with it. On the other hand, the order *Scansores* is a conspicuously unnatural one, and is retained here simply as a matter of convenience.

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* If this view be taken, it will be advisable to give the name of *Saurornithes* to the sub-class, and to reserve the title of *Saururæ* for the order.

SUB-CLASS I. RATITÆ.

ORDER CURSORES.—The first order of Birds is that of the *Cursores*, or Runners, comprising the Ostriches, Rheas, Cassowaries, Emeus, and the singular *Apteryx* of New Zealand. The *Cursores* are characterised by *the rudimentary condition of the wings, which are so short as to be useless for flight, and by the compensating length and strength of the legs.* In accordance with this condition of the limbs, many of the bones retain their marrow, and *the sternum* (fig. 329, A) *is destitute of the prominent ridge or keel, to which the great pectoral muscles are attached* (hence the name of *Ratitæ*, applied by Huxley to the order). In the Ostrich, the pubic bones of the pelvis unite to form a symphysis pubis, as they do in no other bird; and in all, the pelvic arch possesses unusual strength and stability. *The legs are extremely robust and powerful, and the hind-toe is entirely wanting, except in the Apteryx, in which it is rudimentary.* The anterior toes are two or three in number, and are provided with strong blunt claws or nails. *The plumage presents the remarkable peculiarity that the barbs of the feathers, instead of being connected to one another by hooked barbules, as is usually the case, are remote and disconnected from one another, presenting some resemblance to hairs.*

The order *Cursores* may be divided into the two sections of the *Struthionidæ* and the *Apterygidæ*—the former characterised by the absence of the hallux, and comprising the Ostrich, Rhea, Emeu, and Cassowary, with several extinct forms; the latter comprising only the *Apteryx* of New Zealand, and characterised by the possession of a rudimentary hallux.

The African Ostrich (*Struthio camelus*) occurs in the desert plains of Africa and Arabia, and is the largest of all living birds, attaining a height from six to eight feet. The South African Ostrich is often considered as a distinct species, under the name of *S. australis.* The head and neck are nearly naked, and the quill-feathers of the wings and tail have their barbs wholly disconnected, constituting the ostrich-plumes of commerce. The legs are extremely strong, and are terminated by two toes only, these consisting respectively of four and five phalanges, showing that it is the hallux and the innermost toe which are wanting. The internal one of the two toes is much the larger, and is clawed; the outer toe is small and clawless. The pubic bones (fig. 329, B) are united in a ventral symphysis, and the wing is furnished with a long humerus. The Ostriches run with extraordinary speed, and can outstrip the fastest horse. They are polygamous, each male consorting with several females, and they generally keep together in larger or smaller flocks. The eggs are of great size, averaging three pounds each in weight; and the hens lay their eggs in the same nest, this being nothing more than a hole scratched in the sand. The eggs appear to be hatched mainly by the exertions of both parents, relieving each other in the task of incubation, but also partly by the heat of the sun.*

The American Ostriches or *Rheas* are much smaller than the African Ostrich, and have the head feathered, whilst the feet (fig. 329, E) are furnished with three toes each. The wings are rudimentary, and the phalanges are plumed and terminated by a spur. They inhabit the great plains of South America, and are polygamous. Three species are known, extending from Patagonia to Peru, but each inhabiting its own specific area.

The Emeu (*Dromaius Novæ-Hollandiæ*) is exclusively found in the Australian continent, and nearly equals the African Ostrich in size, attaining a height of from five to seven feet. The feet are furnished with three toes each, and the head is

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* Mr Sclater, however, states that the duty of incubation is entirely taken by the males.

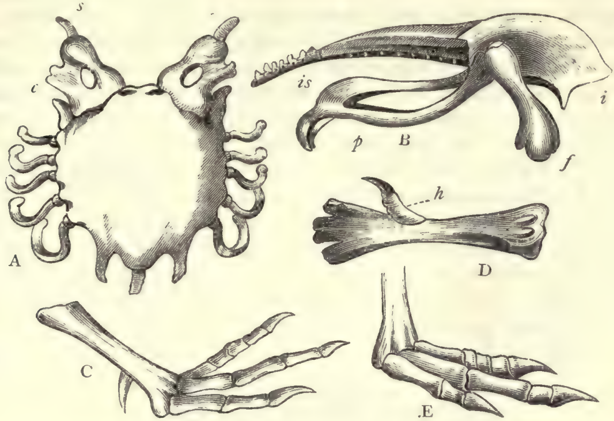

Fig. 329.—Morphology of Cursores. A, Sternum of the Ostrich (*Struthio camelus*): *s* Scapula; *c* Coracoid. B, Side view of the pelvis of the Ostrich: *i* Ilium; *p* Pubis; *is* Ischium; *f* Femur. C, Foot of *Apteryx australis*. D, Tarso-metatarsus of the *Apteryx*, showing the hallux placed high up on its posterior surface. E, Foot of the *Rhea americana*.

feathered. The throat, however, is naked, and the general plumage resembles long hairs, the feathers hanging down on both sides of the body from a central line or parting which runs down the middle of the back. The Emeus are monogamous, and the eggs are dark green in colour. The male Emeu is smaller than the female, and undertakes all the duties of incubation. Two varieties, or species, of the Emeu are known—one on the eastern and the other on the western side of Australia.

The last living group of the *Struthionidæ* is that of the Cassowaries, best represented by the Galeated Cassowary (*Casuarius galeatus*), which inhabits the Moluccan Islands and New Guinea, and was first brought alive to Europe by the Dutch. It stands about five feet in height, and possesses a singular horny crest upon its head. The head and neck are naked, with pendent wattles, the wing has a short humerus, and the feet have three toes each. The general plumage is black, and the feathers more or less closely resemble hairs. The wings are rudimentary, each with five naked pointed quills. The male is much the smaller, and sits upon the eggs. Besides the Galeated Cassowary, other species have been described from the Malayan Archipelago and North Australia, at least nine species being now known to exist in all.

The second section of the Cursorial birds is that of the *Apterygidæ*, comprising only the singular "Kiwis" (*Apteryx*) of New Zealand. The beak in the *Apteryx* is long, slender, and slightly curved, the tip being obtuse, and the nostrils placed at the extremity of the upper mandible. The legs are comparatively short, and there is a rudimentary hind-toe or hallux, forming a kind of spur, furnished with a claw (fig. 329, C and D). The wings are entirely rudimentary, and are quite concealed by the feathers, each terminating in a sharp claw. The feathers are long and narrow, and the tail is short and inconspicuous. The species of *Apteryx* are wholly confined to New Zealand, and are nocturnal in their habits, living upon insects and worms. Four species have been described, of which *A. australis* (fig. 330) is the best known.

As regards the distribution of the *Cursores* in *time*, it seems probable that some of the footprints of the Connecticut Trias (if ornithic at all) have been produced by birds belonging to this group. Leaving these doubtful instances out of sight, the Eocene Tertiary has yielded the first certain traces of Cursorial birds (the *Dasornis* of the London Clay). The most interesting

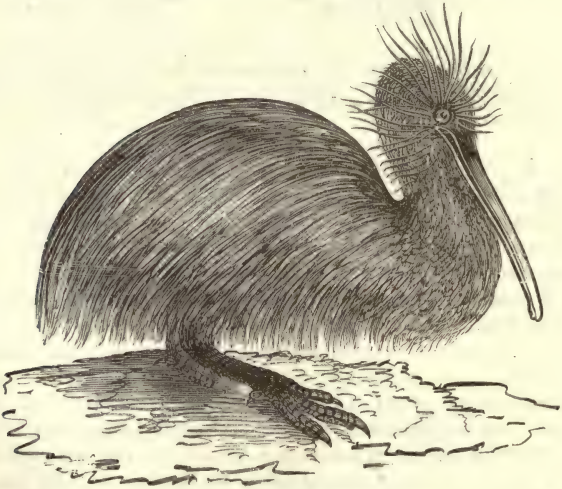

Fig. 330.—*Apteryx australis.* (Gould.)

remains of *Cursores* have, however, been found in the Post-Tertiary deposits of the southern hemisphere, and more especially in New Zealand. In this island have been found the remains of a number of large wingless birds, which form the family of the *Dinornithidæ*, of which *Dinornis* (fig. 331) itself is the most important genus. All the members of this group (*Dinornis*, *Palapteryx*, &c.) are large Cursorial birds, the wings being useless for flight, and furnished with a rudimentary humerus. The hallux is wanting (*Dinornis*) or present (*Palapteryx*). The largest species is the *Dinornis giganteus*, one of the most gigantic of living or fossil birds, the tibia measuring a yard in length, and the total height being at least ten feet. Another species, the *Dinornis elephantopus* (fig. 331), though not stand-

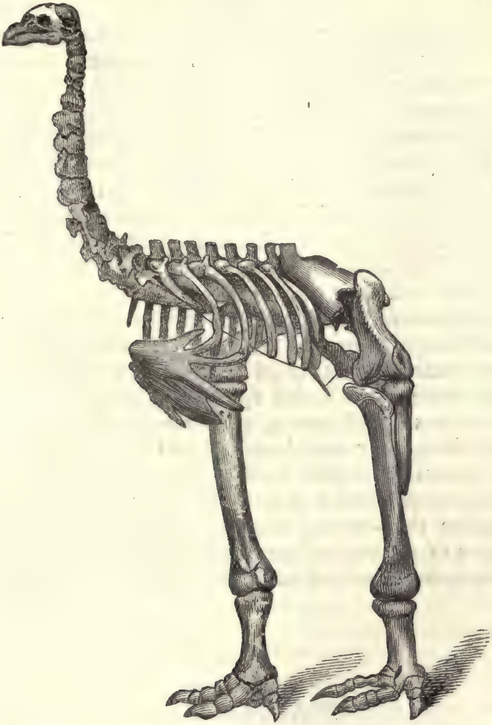

Fig. 331.—Skeleton of *Dinornis elephantopus*, greatly reduced. Post-Pliocene. New Zealand. (After Owen.)

ing more than about six feet in height, was of an even more ponderous construction—"the framework of the skeleton being the most massive of any in the whole class of Birds," whilst "the toe-bones almost rival those of the Elephant" (Owen). The feet in *Dinornis* were furnished with three toes, and are of interest as presenting us with an undoubted bird big enough to produce the largest of the footprints of the Triassic Sandstones of Connecticut. New Zealand has now been so far explored, that it seems questionable if it can retain in its recesses any living example of *Dinornis;* but it is certain that species of this genus were alive during the human period, and survived up to quite a recent date. Not only are the bones very numerous in certain localities, but they are found in the most recent and superficial deposits, and they still contain a considerable proportion of animal matter; whilst in some instances bones have been found with the feathers attached, or with the horny skin of the legs still adhering to them. Charred bones have been found in connection with native "ovens;" and the traditions of the Maories contain circumstantial accounts of gigantic wingless Birds, the "Moas," which were hunted both for their flesh and their plumage.

In Madagascar, bones have been discovered of a bird as large as, or larger than, the *Dinornis giganteus*, which has been described under the name of the *Æpiornis maximus.* With the bones have been found eggs measuring from thirteen to fourteen inches in diameter, and computed to be as big as three ostrich-eggs, or one hundred and forty-eight hen's eggs. Though generally referred to the *Cursores*, *Æpiornis* has been sometimes regarded as a gigantic member of the *Raptores.*

Lastly, the Post-tertiary deposits of Australia have yielded the remains of an extinct Struthious bird allied to the Emeu, which has been described under the name of *Dromæornis.*

CHAPTER LXV.

SUB-CLASS II. CARINATÆ.

NATATORES, GRALLATORES, AND RASORES.

ORDER I. NATATORES (*Palmipedes*).—The order of the *Natatores*, or Swimmers, comprises a number of Birds which are as much or even more at home in the water than upon the land. In accordance with their aquatic habit of life, the *Natatores* have *a boat-shaped body, usually with a long neck. The legs are short, and placed behind the centre of gravity of the body, this position enabling them to act admirably as paddles, at the same time that it renders the gait upon dry land more or less awkward and shuffling. In all cases the toes are "webbed" or united by membrane to a greater or less extent* (fig. 332, A).

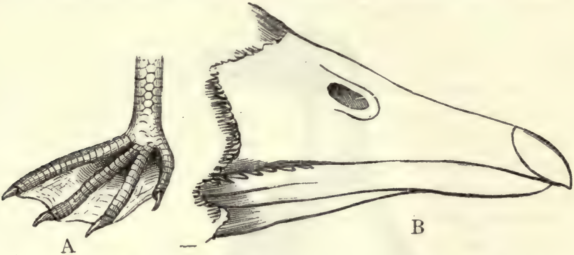

Fig. 332.—Natatores. A, Foot of Cormorant (*Phalacrocorax*); B, Beak of the Bean-goose (*Anser segetum*).

In many instances the membrane or web is stretched completely from toe to toe, but in others the web is divided or split up between the toes, so that the toes are fringed with membranous borders, but the feet are only imperfectly webbed. As their aquatic mode of life exposes them to great reductions of temperature, the body of the Natatorial birds is closely covered with feathers, and with a thick coating of down next the skin. They are, further, prevented from becoming wet in the water by the great development of the coccygeal oil-gland, by means of which the lustrous plumage is kept constantly lubricated and waterproof. They are usually polygamous, each male consorting with several females; and the young are hatched in a condition not requiring any special assistance from the parents, being able to swim and procure food for themselves from the moment they are liberated from the egg.

The *Natatores* are divided into the following four families:—

Fam. 1. *Brevipennatæ.*—In this family of the Swimming birds the wings are always short, and are sometimes useless as organs of flight, the tail is very short, and the legs are placed very far back, so as to render terrestrial progression very difficult or awkward. The family includes the Penguins, Auks, Guillemots, Divers, and Grebes. In the Penguins (*Spheniscidæ*) the wings are completely rudimentary, without quills, and covered with a scaly skin. They are useless as far as flight is concerned, but they are employed by the bird as fins, enabling it to swim under water with great facility, and they are also used on the land as fore-legs. The feet are webbed, and the hinder toe is rudimentary or wanting. The Penguins live gregariously in the seas of the southern hemisphere, on the coasts of South Africa and South America, especially at Tierra del Fuego, and in the solitary islands of the South Pacific. When on land the Penguins stand bolt upright, and as they usually stand on the shore in long lines they are said to present a most singular appearance. The best-known species are the Jackass Penguin (*Spheniscus demersus*) of the Falkland Islands, and the King Penguin (*Aptenodytes Patagonica*) of the Straits of Magalhaens. Some Penguins have the extraordinary habit of forming no nest, but of carrying their egg about with them in a temporary pouch of the abdominal integument. In the Auks (*Alcidæ*) the wings are better developed than in the Penguins, and they contain true quill-feathers; but they are

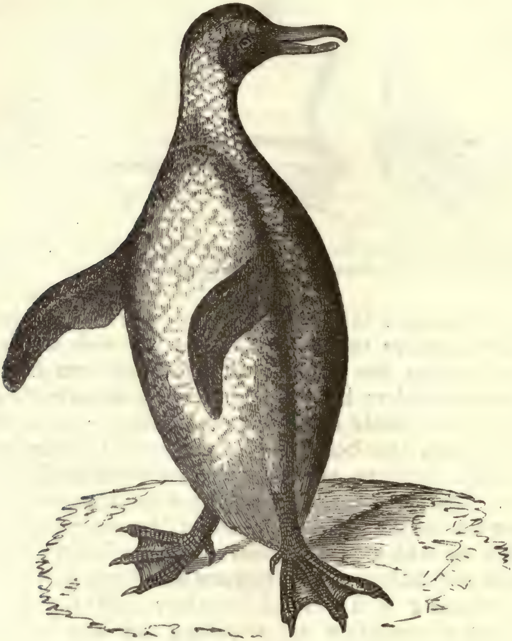

Fig. 333.—Jackass Penguin (*Spheniscus demersus*).

still short as compared with the size of the body, and are of more use as fins than for flight. The Great Auk or Gare-fowl (*Alca impennis*) is remarkable for being one of the birds which appear to have become entirely extinct within the human period, having been, in fact, destroyed by man himself. It abounded at one time on both the American and European sides of the North Atlantic, and used to visit the shores of Scotland in summer for the purpose of breeding. The Little Auk (*Mergulus alle*) occurs still in abundance in the seas of northern regions. Other well-known members of this group are the Razor-bill, the Puffins (*Fratercula arctica*), and the Guillemots (*Uria*). The Guillemots have a short tail, narrow and pointed wings, short feet, and no hallux. Like the other members of the family they inhabit northern and polar regions.

In the Divers (*Colymbidæ*), comprising the true Divers and the Grebes, the power of flight is pretty well developed, but the bird still is much more active in the water, swimming or diving, than on land. The Grebes are not uncommon in Britain, and are largely killed for making muffs, collars, and other articles of winter dress. They have the membrane between the toes deeply incised. They haunt the sea as well as lakes and rivers, and swim and dive admirably. In the Divers proper the front toes are completely united by a membrane. The Northern Diver or Loon (*Colymbus glacialis*) is a familiar example, and is found on the coasts of high northern latitudes.

Fam. 2. *Longipennatæ.*—This family of *Natatores* is characterised by the well-developed wings, the pointed, sometimes knife-like, sometimes hooked bill, and by never having the hallux united with the anterior toes by a membrane. The following are the more important groups coming under this head:—

a. Laridæ, or Gulls and Terns, having powerful wings, a free hinder toe, and the three anterior toes united by a membrane. The Gulls form an exceedingly large and widely distributed group of birds; and the Terns or Sea-swallows are equally beautiful, if not quite so common. The Terns are distinguished by their long and pointed wings, forked tail, and comparatively short legs. They fly with great rapidity over the surface of the sea, from which they pick up their food.

b. Procellaridæ, or Petrels, closely resembling the true Gulls, but having a rudimentary hinder toe, and having the upper mandible strongly hooked. The smaller species of Petrel are well known to all sailors under the name of Storm-birds and Mother Carey's Chickens. They are nocturnal or crepuscular in their habits, breed in holes in the rocks, lay but one egg, and are almost all of small size and more or less sombre plumage. The largest member of the group is the gigantic Albatross (*Diomedea exulans*), not uncommonly found far from land in both the northern and southern oceans. The Albatross sometimes measures as much as fifteen feet from the tip of one wing to that of the other, and the flight is powerful in proportion.

Fam. 3. *Totipalmatæ*, characterised by having the hinder toe or hallux more or less directed inwards, and united to the innermost of the anterior toes by a membrane (fig. 332, A). In this family are the Pelicans, Cormorants, Gannets, Frigate-birds, Darters, and others. They all fly well, and have short legs, and amongst them are almost the only Natatorial Birds which ever perch upon trees.

The Pelicans (*Pelicanidæ*) are large birds, which subsist on fish, and are found in Europe, Asia, Africa, and the New World. They sometimes measure as much as from ten to fifteen feet between the tips of the wings, and most of the bones are pneumatic, so that the skeleton is extremely light. The lower mandible is composed of two flexible branches which serve for the support of a large "gular" pouch, formed by the loose unfeathered skin of the neck. The fish captured by the bird are temporarily deposited in this pouch, and the parent birds feed their young out of it. The bill is long and straight, and the upper mandible is strongly hooked at the tip.

In the Cormorants (*Phalacrocorax*) there is no pouch beneath the lower mandible, but the skin of the throat is very lax and distensible; the nail of the middle toe is serrated. They are widely distributed over the world, one species being very abundant in many parts of Europe. The Gannets (*Sula*) have a compressed bill, the margins of which are finely crenate or toothed. They occur abundantly on many parts of the coasts of northern Europe, one of the most noted of their stations being the Bass Rock at the mouth of the Firth of Forth. Another species (*Sula variegata*) is of greater importance to man, as being one of the birds from the accumulated droppings of which guano is derived. The Frigate-birds (*Tachypetes*) are chiefly remarkable for their extraordinary powers of flight, conditioned by their enormously long and powerful wings and long forked tail. They occur on the coasts of tropical America, and are often found at immense distances from any land. The Tropic-birds (*Phaeton*) inhabit inter-tropical regions, and are found far out at sea. They have short feeble feet, and long pointed wings.

The Darters or Snake-birds (*Plotus*) are somewhat aberrant members of this group, characterised by their elongated necks and long pointed bills. They occur in America, Africa, and Australia, and catch fish by suddenly darting upon them from above.

Fam. 4. *Lamellirostres.*—The last family of the *Natatores* is that of the *Lamellirostres*, including the Ducks, Geese, Swans, and Flamingoes, and characterised by the form of the beak (figs. 332 and 334), which is flattened in form and covered with a soft skin. The edges of the bill are further furnished with a series of transverse plates or lamellæ, which form a kind of fringe or "strainer," by means of which these birds sift the mud in which they habitually seek their food. The bill is richly supplied with filaments of the fifth nerve, and doubtless serves as an efficient organ of touch. The feet are furnished with four toes, of which three are turned forwards, and are webbed, whilst the fourth is turned backwards, and is free. The trachea in the males is often enlarged or twisted in its lower part, and co-operates in the production of the peculiar clanging note of most of these birds. The body is heavy, and the wings only moderately developed.

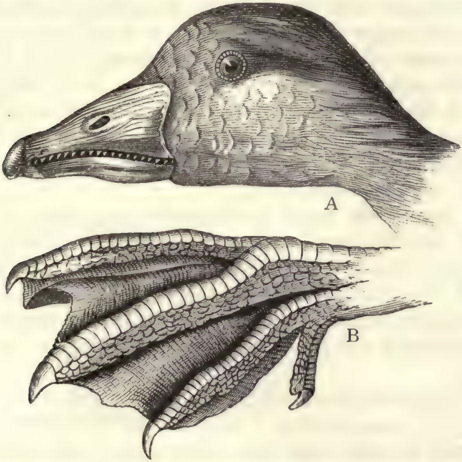

Fig. 334.—A, Head of the Grey Lag Goose; B, Foot of the domestic Goose.

The groups of the Ducks (*Anatidæ*), Geese (*Anserinæ*), and Swans (*Cygnidæ*), are too familiar to require much special notice. The *Anatidæ*, or true Ducks, have the hallux furnished with a very narrow membranous lobe, and the laminæ of the upper mandible generally projecting. As examples may be taken the Mallards and Teals (*Boschas*), the Widgeons (*Mareca*), the Shoveller (*Anas*), and the Pin-tail Ducks (*Dafila*). The Sea-ducks (*Fuligulinæ*) frequent the sea chiefly, and have the hallux furnished with a wide membranous lobe. Good examples are the Eider-duck (*Somateria*), the Surf-duck (*Oidemia*), the Canvass-back Duck and Pochard (*Fuligula*), and the Golden-eye (*Clangula*).

The *Anserinæ* are distinguished from the Ducks chiefly by their stronger and longer legs, and comparatively shorter wings. Good examples are the Grey Lag (*Anser ferus*), the Canada Goose (*A. canadensis*), the Bean-goose (*A. segetum*), and the Snow-goose (*A. hyperboreus*). All the domesticated varieties of Geese appear to be undoubtedly descended from the "Grey Lag" Goose, a common wild species which is found in marshy districts in Europe generally, in Northern Africa, and as far east as Persia.

In the Swans the neck is extremely long, and the legs are short. In the Hooper Swan (*Cygnus ferus*) the sternal keel is double, and forms a cavity for the reception of a convoluted portion of the trachea. This is not the case, however, with the Mute Swan (*C. olor*), the Black Swan (*C. atratus*), or the Trumpeter Swan (*C buccinator*), all well-known members of the group.

The Flamingoes, however, forming the group of the *Phœnicopteridæ*, require some notice, if only for the fact that the legs are so long and slender that they have often been placed in the order *Grallatores* on this account. The three anterior toes, however, are webbed or completely united by membrane, and the bill is lamellate, so that there can be little hesitation in leaving the Flamingo in its present position amongst the *Natatores*. The bill is singularly bent, both mandibles being suddenly curved downwards from the middle. The common Flamingo (*Phœnicopterus ruber*) occurs abundantly in various parts of southern Europe. It stands between three and four feet in height, the general plumage being rose-coloured, the wing-coverts red, and the quill-feathers of the wings black. The tongue is fleshy, and one of the extravagances of the Romans during the later period of the Empire was to have dishes composed solely of Flamingoes' tongues. Other species occur in South America and Africa.

As regards the distribution of the *Natatores* in *time*, the earliest traces of the order are found in the Cretaceous rocks. In deposits of this age in the United States, Professor Marsh has exhumed the bones of several forms (*Graculavus* and *Laornis*); and other forms (*Cimolornis*) have been described from the Cretaceous of Europe. In the Eocene Tertiary are found several Natatorial birds, the most interesting of which are the *Gastornis Parisiensis* and *Agnopterus* of the Paris basin, the former being apparently a huge and wingless goose, whilst the latter is allied to the Flamingoes. Under this order also probably comes the extraordinary fossil bird, recently described by Professor Owen, from the London Clay (Eocene) of Sheppey under the name of *Odontopteryx toliapicus*. In this singular bird (fig. 335) the alveolar margins of both jaws are furnished with tooth-like denticulations, which differ from true teeth in being actually parts of the osseous substance of the jaw itself, with which they are continuous. They are of triangular or compressed conical form, and are of two sizes, the larger ones resembling canines. From the consideration of all the discovered remains of this bird, Professor Owen concludes that "*Odontopteryx* was a warm-blooded feathered biped, with wings; and further, that it was web-footed and a fish-eater, and that in the catching of its slippery prey it was assisted by this Pterosauroid armature of its jaws." Upon the whole, *Odontopteryx* would appear to be most nearly allied to the *Anatidæ*, but the denticulation of its jaws is an entirely unique character.

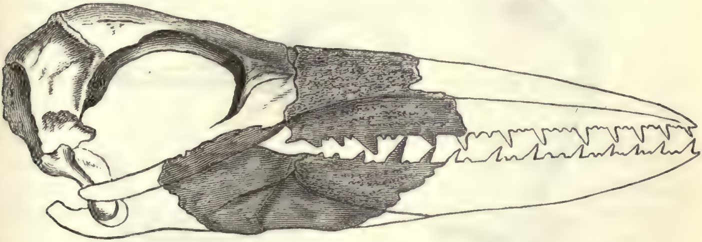

Fig. 335.—Skull of *Odontopteryx toliapicus*, restored. (After Owen.)

Leaving the Eocene, the Miocene and later Tertiary deposits have yielded the remains of numerous Swimming Birds, as has also the Post-tertiary; but no special interest attaches to any of these, unless the great *Cnemiornis* of the Quaternary of New Zealand be rightly referred here, since this has the peculiarity of having been unable to fly.

ORDER II. GRALLATORES.—The birds comprising the order of the *Grallatores*, or Waders, for the most part frequent the banks of rivers and lakes, the shores of estuaries, marshes, lagoons, and shallow pools, though some of them keep almost exclusively to dry land, preferring, however, moist and damp situations. In accordance with their semi-aquatic amphibious habits, the Waders are distinguished by *the great length of their legs; the increase in length being mainly due to the great elongation of the tarso-metatarsus. The legs are also unfeathered from the lower end of the tibia downwards. The toes are elongated and straight* (fig. 336, A), *and are never completely palmate, though sometimes semi-palmate. There are three anterior toes, and usually a short hallux, but the latter may be wanting.* The wings are long, and the power of flight usually considerable; but the tail is short, and the long legs are stretched out behind in flight to compensate for the brevity of the tail. The body is generally slender, and the neck and beak usually of considerable length (fig. 336, B). They are sometimes polygamous, sometimes monogamous, and the young of the former are able to run about as soon as they are hatched.

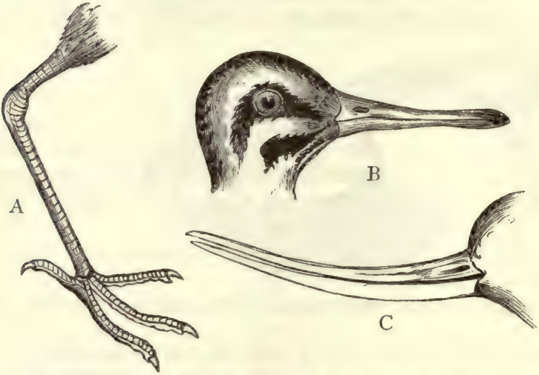

Fig. 336.—Grallatores. A, Leg and foot of the Curlew; B, Head of Snipe; C, Beak of the Avocet.

The most typical Waders—those, namely, which are semi-aquatic in their habits—spend most of their time wading about in shallow waters or marshes, feeding upon small fishes, worms, shell-fish, or insects. Others, such as the Storks, live mostly upon the land, and are more or less exclusively vegetable-feeders.

The *Grallatores* are divided into the four families of the *Macrodactyli*, the *Cultirostres*, the *Longirostres*, and the *Pressirostres*.

Fam. 1. *Macrodactyli.*—In this family the feet are furnished with four elongated, sometimes lobate, toes, and the wings are of moderate or less than average size. In many of their characters a considerable number of the birds of this family approach the Rasorial birds, and differ from the true Waders. The beak is mostly short, rarely longer than the head, and is compressed from side to side, or wedge-shaped. The legs are strong and not particularly lengthy; but the toes are often of great length, and are furnished with long claws. The neck is not very long, and the tail is very short. Some of them are strictly aquatic in their habits, and, like the Coots, approach in many respects to the *Natatores;* others, again, are exclusively terrestrial. The most familiar members of this family are the Rails (*Rallus*), Water-hens (*Gallinula*), the Coots (*Fulica*), and the Jacana (*Parra jacana*). The Water-hens and Coots are aquatic or semi-aquatic, swimming and diving with great ease. In the Coots the toes are semi-palmate, being bordered by membranous lobes, like the toes of the Grebes, but the toes are not fringed in the Gallinules. Amongst the Coots should probably be placed the *Notornis* (Owen), long supposed to be extinct, but recently proved to be still living in the Middle Island of New Zealand. The *Notornis* is much larger than the ordinary Coots, and is remarkable in the fact that, like many extinct and some living New Zealand birds, the wings are so rudimentary as to be useless for flight. The true Rails, comprising the common Water-rail (*Rallus aquaticus*), and the Land-rail or Corn-crake (*Crex pratensis*) of Britain, and the Marsh-hen (*Rallus elegans*), and Virginian Rail (*R. Virginianus*) of North America, live almost exclusively on land, though the first of these usually frequents damp or marshy places. In the Jacanas, lastly, the feet are furnished with excessively long and slender toes, which enable the bird to run about upon the leaves of aquatic plants; whilst the carpus is armed with formidable spurs. They are natives of South America, Africa, and India. Closely allied to the Jacanas are the Screamers (*Palamedea*) of South America, of which the Horned Screamer (*P. cornuta*) is the best known. It has a long frontal horn, and has spurs implanted on the edge of the wing.

Fam. 2. *Cultirostres.*—In this family of the *Grallatores* are some of the most typical and familiar forms contained in the entire order. The bill in this family is long—usually longer than the head—and is compressed from side to side; the legs are long and slender, having a considerable portion of the tibiæ unfeathered; and the feet have four toes, which are usually connected to a greater or less extent at their bases by membrane. In this family are the Cranes, Herons, Stork, Ibis, Spoonbill, and others of less importance.

The Cranes (*Gruidæ*) are large and elegant birds, and are chiefly remarkable for their long migrations, which were noticed by many classical authors. In these journeys the Cranes usually fly in large flocks, led by a single leader, so that the whole assemblage assumes a wedge-like form; or they fly in long lines. The common Crane (*Grus cinerea*) breeds in the north of Europe and Siberia, and migrates southwards at the approach of winter. The Numidian Crane or Demoiselle inhabits Asia and Africa, the Stanley Cranes (*Anthropoides*) are natives of the East Indies, and the Crowned Cranes (*Balearica*) are African. In many respects the Cranes are more nearly allied to the Rails than to the Herons. The Herons (*Ardeidæ*) are familiarly known to every one in the person of the common Grey or Crested Heron (*Ardea cinerea*, fig. 337). It was one of the birds most generally pursued in the now almost extinct sport of falconry. Various species of Heron are found over the whole world, both in temperate and hot climates. Here, also, belong the various species of Night Heron (*Nycticorax*), the Bitterns (*Botaurus*), and the Boat-bills (*Cancroma*).

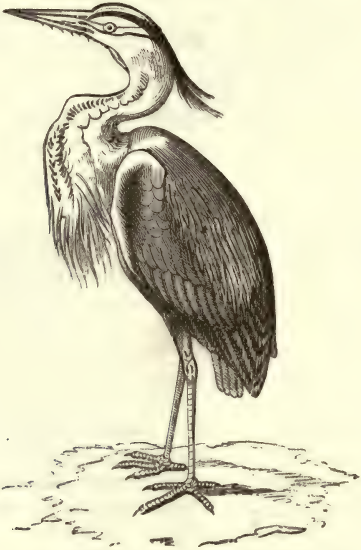

Fig. 337.—Crested Heron (*Ardea cinerea*). Europe.

The Ibises (*Tantalinæ*) form a group of beautiful birds, species of which occur in all the warm countries of the world. They are distinguished by their metallic colours, long, cylindrical, curved bill, and more or less naked head. One, the *Ibis religiosa*, was regarded by the ancient Egyptians as a deity, and was treated with divine honours, being often embalmed along with their mummies, or figured on their monuments.

The Storks (*Ciconinæ*) are large birds, of which one, the common Stork (*Ciconia alba*), is rarely found in Britain, but occurs commonly on the Continent, where it is often semi-domesticated. The Storks live in marshes, and feed on frogs, fishes, &c. Nearly related to the true Storks are the gigantic Marabout (*Mycteria Marabou*) and Adjutant (*M. Argala*) of Africa and India, which possess a sausage-shaped appendage in front of the neck.

The Spoonbills (*Plataleadæ*) are also large birds, very like the Storks, but the bill is flattened out so as to form a broad spoon-like plate. The common White Spoonbill (*Platalea leucorodia*) is found commonly on the Continent, but is of very rare occurrence in Britain.

Fam. 3. *Longirostres.*—The third family of Waders is that of the *Longirostres*, characterised by the possession of long, slender, soft bills, grooved for the perforations of the nostrils (fig. 336, B). The legs are sometimes rather short, sometimes of great length; the toes are of moderate length, and the hallux is usually short, and is sometimes absent. The bill in these birds serves as an organ of touch, being used as a kind of probe to feel for food in mud or marshy soil. To fulfil this purpose, the tip of the bill is furnished with numerous filaments of the fifth nerve. They feed mostly upon insects and worms, and are not strictly aquatic in their habits, mostly frequenting marshy districts, moors, fens, the banks of rivers or lakes, or the shores of the sea.

In this family of the Long-billed Waders are the various species of Snipe and Woodcock (*Scolopacidæ*), the Sandpipers (*Tringa*), the Curlews (*Numenius*), the Turnstones (*Strepsilas*), the Ruffs (*Machetes*), the Redshanks (*Totanus*), the Godwits (*Limosa*), and others which need no special notice.

Fam. 4. *Pressirostres.*—The members of this family are characterised by the moderate length of the bill, which is seldom longer than the head, and has a compressed tip. The legs are long, but the toes are short, and are almost always partially connected together at their bases by membrane. The hallux is short, and is often wanting. The wings are long, and they can both fly powerfully and run with great swiftness. In this section are two very distinct sub-families, the *Charadriidæ* or Plovers, and the *Otidæ* or Bustards. In the former of these the legs are long and slender, the toes are united at their bases by a small membrane, and the hind-toe is very small and raised above the ground, or is entirely wanting. In this group are the true Plovers and Lapwings (*Charadrius* and *Vanellus*), the Pratincoles (*Glareola*), the Long-shanks (*Himantopus*), the Oyster-catcher (*Hæmatopus*), and the Thick-knee (*Œdicnemus*). In the *Otidæ* or Bustards, the legs are long, and the toes are short and furnished with stout claws. The hinder toe or hallux is entirely wanting; and these birds are chiefly interesting from the affinities which they exhibit to the *Rasores* on the one hand, and to the *Cursores* (Ostrich, &c.) on the other. The wings, however, are of ample size, and the tail is comparatively long, the reverse being the case in the *Cursores*. The Bustards are entirely confined to the Old World, and two species were formerly not uncommon in Britain. They are found in plains and downs, and rarely fly, but run with great swiftness, using the wings to accelerate their course. They are polygamous, and the males are generally brighter and more variegated in plumage than the females.

As regards their *distribution* in *time*, the earliest known remains of *Grallatores* have been found in the Cretaceous rocks of North America (*Telmatornis* and *Palæotringa*). The Eocene Tertiary of both Europe and North America has yielded the remains of Waders, one of the most remarkable being a gigantic Rail (*Gypsornis*) from the Paris basin. The later Tertiaries also contain the remains of various Grallatorial birds allied to, or identical with, living types. In the Post-tertiary deposits of Mauritius are found the bones of the *Aphanapteryx*, a large Ralline bird, allied to the living *Ocydromus*, but incapable of flight. It survived into the human period, and was exterminated at a comparatively late date.

ORDER III. RASORES.—The third order of Carinate Birds is that of the *Rasores*, or Scratchers, often spoken of collectively as the "Gallinaceous" birds, from the old name of "Gallinæ," given to the order by Linnæus. The *Rasores* are characterised by *the convex, vaulted upper mandible, having the nostrils pierced in a membranous space at its base. The nostrils are covered by a cartilaginous scale.* Taking the *Gallinacei* as the type of the order, the *legs are strong and robust, mostly covered with feathers as far as the joint between the tibia and tarso-metatarsus. There are four toes, three in front and one behind, the latter being short, and placed at a higher level than the other toes. All the toes terminate in strong blunt claws suitable* *for scratching* (fig. 338, A). The food of the Scratchers or Gallinaceous birds consists chiefly of hard grains and seeds, and in accordance with this they have a capacious crop and an extremely strong and muscular gizzard. They mostly nidificate, or build their nests, upon the ground, and the more typical members of the order are polygamous. The males take no part in either nidification or incubation, and the young are generally "precocious," being able to run about and provide themselves with food from the moment they quit the egg. The young of the Pigeons and Doves, however, are brought forth in a comparatively helpless condition. The wings in the majority of the *Rasores* are more or less weak, and the flight is feeble and accompanied with a whirring sound. Many of the Pigeons, however, are capable of very powerful and sustained flight.

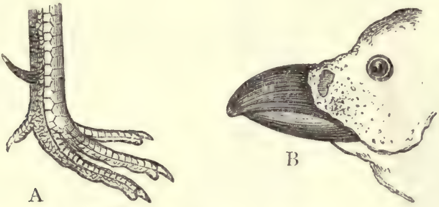

Fig. 338.—Rasores. A, Foot of Fowl (*Gallus Bankiva*); B, Head of Guinea-fowl.

The order *Rasores* is divided into two sub-orders, called respectively the *Gallinacei* and the *Columbacei*, or sometimes, from the characters of the sounds which they utter, the *Clamatores* and the *Gemitores.*

Sub-order 1. *Gallinacei* or *Clamatores.*—This sub-order comprises the typical members of the order *Rasores*, such as the common Fowls, Turkeys, Partridge, Grouse, Pea-fowl, and a number of allied forms. Its characters are therefore those of the order itself, but it is especially distinguished from the *Columbacei* by being less fully adapted for flight. The body is much heavier, comparatively speaking, the legs and feet are stronger, and the wings shorter and less powerful. On the whole, therefore, these birds are worse fliers than the *Columbacei*, and are better adapted for living upon the ground. The hallux (fig. 339, A) is elevated above the anterior toes, and merely touches the ground in walking. The back of the tarsus, too, is usually furnished in the males with a spur (*calcar*), which is used as an offensive weapon, and has sometimes been looked upon as a rudimentary toe.* Lastly, the *Gallinacei* are mostly polygamous, and the males are usually much more brilliantly coloured than the females, this being an adaptive modification of the plumage to meet this peculiarity in their mode of life.†

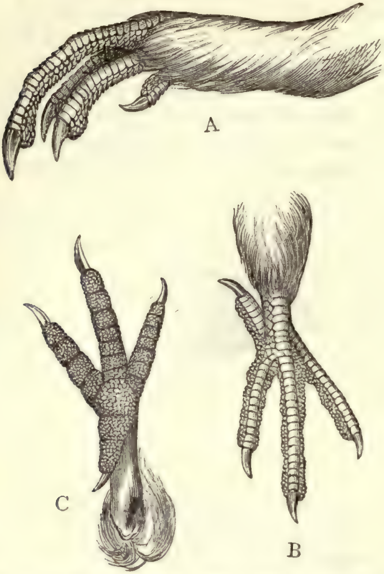

Fig. 339.—A, Foot of Black-cock (*Tetrao tetrix*). B and C, Upper and under views of the foot of the Wood-pigeon (*Columba palumbus*).

The following are the most important families of the *Gallinacei*:—

The *Tetraonidæ*, or Grouse family, comprises the various species of Grouse (*Tetrao*), the Ruffed Grouse (*Bonasa*), the Cock of the Plains (*Centrocercus*), and the Ptarmigans (*Lagopus*).

The *Perdicidæ*, or Partridge family, comprises the Partridges (*Perdix*), the Francolins (*Francolinus*), the Quails (*Coturnix*), the Maryland Quail (*Ortyx*), the Tufted Quails (*Lophortyx*), &c.

The *Phasianidæ*, or Pheasant family, comprises the Turkeys and Guinea-fowl (*Meleagrinæ*), the common Pheasant (*Phasianus Colchicus*), the Golden and Silver Pheasants, the common Fowl (*Gallus domesticus*), and the Pea-fowl (*Pavoninæ*). None of these birds —all of which can be domesticated, and most of which are of great value to man—are natives of this country, though they will all breed readily, and thrive even in confinement. The domestic Turkey (*Meleagris gallopavo*) is originally a native of North America, where it still occurs in a wild condition, having been brought to Europe about the beginning of the sixteenth century. The Guinea-fowl (*Numida meleagris*) is originally an African bird. The common Pheasant (*Phasianus Colchicus*), though now regarded as an indigenous bird, truly belongs to Asia, and it is asserted that it was really brought to Europe from Colchis by the Greeks; hence its specific name. The common Fowl is certainly not a native of Europe, and it is usually thought to be a native of Asia or of some of the Asiatic islands; but its exact original habitat is uncertain, as is the species from which the domestic breeds are descended (commonly said to be the *Gallus Bankiva* of Java). The introduction of the Fowl into Europe is lost in the mists of antiquity, and it is wholly unknown whence the original stock may have been brought; though there is really every ground for believing that the typical breed—the Game breed—is truly descended from the Jungle Cock, or *Gallus Bankiva.* The domestic Fowl has, however, been found to be a member of the Cave-fauna of France in the early Stone period, which would throw far back its alleged introduction from the East. The Pea-fowl (*Pavo*) are really natives of Thibet and Hindostan, and were originally brought to Greece by Alexander the Great. They were formerly much esteemed as food, but are now regarded merely from an ornamental point of view.

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* In some cases (as in the Java Peacock) the female possesses spurs as well as the male; and sometimes (as in *Polyplectron*) there are two or more spurs on each leg of the male.

† The Guinea-fowl, Red Grouse, Ptarmigan, and Partridge are monogamous, in a state of nature at any rate.

The *Pteroclidæ,* or Sand-grouse, are confined to the Old World, being principally Asiatic and African, and in their long and pointed wings they make an approximation to the Pigeons.

The *Turnicidæ*, or Bush-quails, on the other hand, make an approach to the *Charadriidæ* amongst the *Grallatores.* They are found in Europe, Africa, Asia, and Australia.

The *Megapodidæ*, or Mound-birds, belong to India and Australia, and have very large feet and long claws. They build immense mounds, often six or eight feet high, and twenty or thirty feet in diameter. They lay their eggs in the centre of these mounds at a depth of two or three feet, and leave them to be hatched by the heat produced by the fermentation of the vegetable matter of the mass.

The *Cracidæ,* or Curassows, are large heavy birds, allied to the preceding, belonging to Central and South America, and to a great extent arboreal in their habits. The best-known species is the crested Curassow (*Crax alector*) of Mexico and Brazil.

Lastly, the *Tinamidæ,* or Tinamous, form an aberrant group of the *Gallinacei,* with many remarkable features in their internal organisation, and with the striking external character that the tail is exceedingly short or totally wanting. They inhabit South America, and are in many respects intermediate between the *Struthionidæ* and the true *Gallinæ*, such as the Grouse. Many of the sutures of the skull are persistent, and the brain is very small. There is the lacertilian character that there exists a row of supra-orbital bones.

Sub-order 2. *Columbacei.*—The second sub-order of the *Rasores* is that of the *Columbacei* or *Gemitores*, comprising the Doves and Pigeons, and often raised to the rank of a distinct order under the name of *Columbæ*. The *Columbacei* are separated from the more typical members of the *Rasores* by being furnished with strong wings, so as to endow them with considerable powers of flight. In place, therefore, of being chiefly ground-birds, they are to a great extent arboreal in their habits, and in accordance with this the feet are slender, and are well adapted for perching. There are four toes, three in front and one behind, and the former are never united towards their bases by a membrane, though the base of the outer toe is sometimes united to that of the middle toe. The hallux is articulated on the same plane as the other toes, and touches the ground in walking. Lastly, they are all monogamous, and pair for life; in consequence of

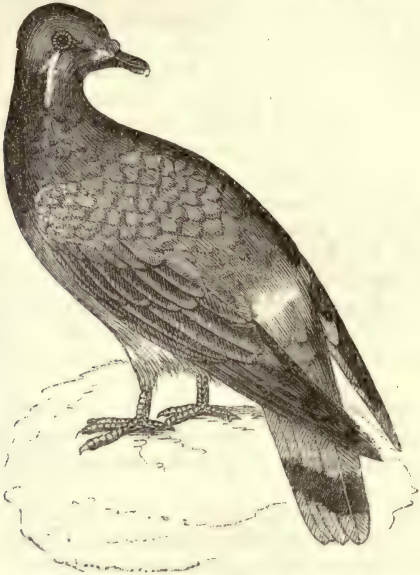

Fig. 340.—Columbidæ. Rock-pigeon (*Columba livia*).

which fact, and of their being readily susceptible of domestication, they present an enormous number of varieties, often so different from one another that they would certainly be described as distinct species if found in a wild state. It seems certain, however, that all the common domestic breeds of Pigeons, however unlike one another, are really descended from the Rock-pigeon (*Columba livia*), which occurs wild in many parts of Europe, and has retained its distinguishing peculiarities unaltered for many centuries up to the present day. Finally, the young of the *Columbacei* are born in a naked and helpless state, whilst those of the *Gallinacei* are "precocious," and can take care of themselves from the moment of their liberation from the egg.

Of the various living birds included in this section, the true Pigeons (*Columbidæ*) are too well known to require any description; but the Ground-pigeons (*Gouridæ*) depart to some extent from this type, being ground-loving birds, more closely allied to the ordinary *Gallinacei.* The *Treronidæ*, or Tree-pigeons, are exclusively found in the Old World, in its warmer parts, and are arboreal in their habits, living principally upon fruits. The *Didunculidæ* are a small group, comprising only the little *Didunculus strigirostris* of the Navigator Islands. In this curious bird the wings are well developed, enabling it to lead an arboreal life, and the upper mandible of the beak is strongly arched and hooked towards its tip. The *Didunculus* is of special interest as having certain relationships to the now extinct Dodo, the representative of the family *Dididæ.* The Dodo (*Didus ineptus*, fig. 341) formerly inhabited the island of Mauritius, in great numbers, but the last record of its occurrence dates from the year 1681. It was a large and heavy bird, bigger than a swan, and entirely unlike the Pigeons in general appearance. The wings were rudimentary and completely useless as organs of flight. The legs were short and stout, the feet had four toes each, and the tail was extremely short, carrying, as well as the wings, a tuft of soft plumes. The beak (unlike that of any of the *Columbacei* except the little *Didunculus strigirostris*) was strongly arched towards the end, and the upper mandible had a strongly-hooked apex, not at all unlike that of a bird of prey. The Dodo owed its extermination to the fact that it was good to eat, and that it was unable to fly. At present all the known remains of this singular bird that exist are some old, but apparently faithful, oil-paintings, and a few fragmentary remains, to which explorations in the Recent deposits of the island have added a large number of bones. Allied to the Dodo, and, like it, incapable of flight, is the Solitaire (*Pezophaps*) of Rodriguez, a small island lying about 300 miles to the east of Mauritius. Its last recorded appearance was in the year 1693. It had longer legs than the Dodo, and its bill was less strongly arched.

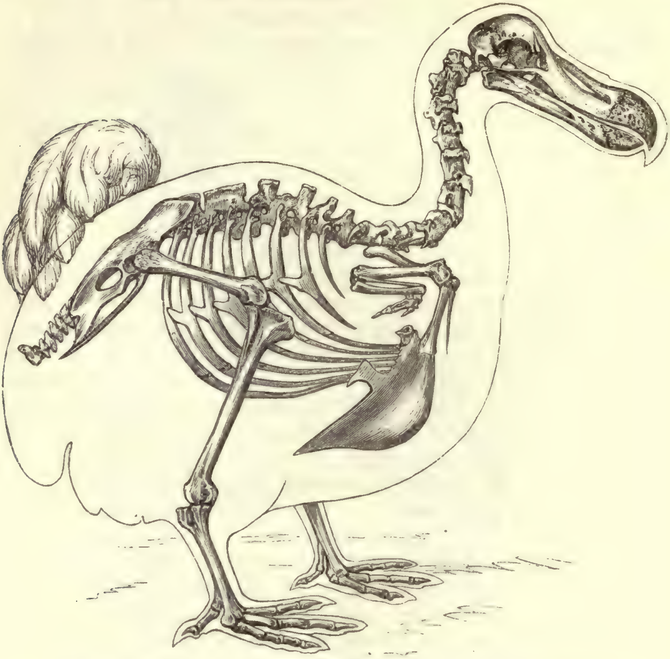

Fig. 341.—Skeleton of the Dodo (*Didus ineptus*), restored. (After Owen.)

As regards the distribution of the *Rasores* in *time*, the order is not known to have made its appearance sooner than the Eocene Tertiary (the *Palæortyx* of the Paris basin). In the Miocene period occur the remains of both Gallinaceous and Columbaceous birds, one of the most noticeable of the former being a Turkey (*Meleagris antiquus*) from the Miocene of Colorado. The later Tertiary and Post-tertiary deposits have also yielded the bones of various Rasorial birds.

CHAPTER LXVI.

SUB-CLASS CARINATÆ—Continued.

SCANSORES, INSESSORES, AND RAPTORES.

ORDER IV. SCANSORES.—The order of the Scansorial or Climbing birds is easily and very shortly defined, having no other distinctive and exclusive peculiarity except the fact that *the feet are provided with four toes, of which two are turned backwards and two forwards. Of the two toes which are directed backwards, one is the hallux or proper hind-toe, and the other is the outermost of the normal three anterior toes.* This arrangement of the toes (fig. 342, B) enables the *Scansores* to climb with unusual facility. Their powers of flight, on the other hand, are generally only moderate and below the average. Their food consists of insects or fruit. Their nests are usually made in the hollows of old trees, but some of them have the remarkable peculiarity that they build no nests of their own, but deposit their eggs in the nests of other birds. They are all monogamous.

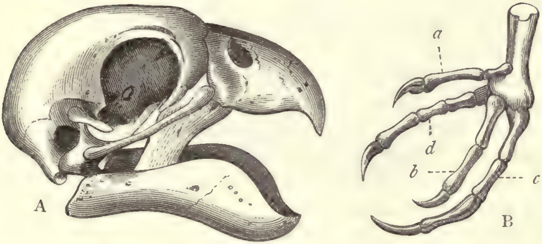

Fig. 342.—A, Skull of a Parrot (*Psittacus erythacus*). B, Foot of the same: *a* Hallux; *b* Index; *c* Middle toe; *d* Outer or ring toe. (After Blanchard.)

The order *Scansores*, as above defined, must be looked upon as a purely artificial assemblage, comprising birds which possess in common the peculiarity of a scansorial foot, but which otherwise are widely different. The order is only retained here because it can hardly be dispensed with otherwise than by raising the three principal groups contained in it to the rank of separate orders (viz., the *Cuculidæ*, *Picidæ*, and *Psittacidæ*).

The most important families of the *Scansores* are the Cuckoos (*Cuculidæ*), the Woodpeckers and Wry-necks (*Picidæ*), the Parrots (*Psittacidæ*), the Toucans (*Rhamphastidæ*), the Trogons (*Trogonidæ*), the Barbets (*Bucconidæ*), and the Plantain-eaters (*Musophagidæ*).

The *Cuculidæ*, or Cuckoos, are chiefly remarkable for the extraordinary fact that many of them, instead of nidificating and incubating for themselves, lay their eggs in the nests of other birds. The only bird not belonging to this family which has the same "parasitic" habit, is the Cow-bunting (*Molothrus pecoris*) of the United States. As a rule, only one egg is deposited in each nest, and the young Cuckoo which is hatched from it, is brought up by the foster-parent, generally at the expense of the legitimate offspring. The large Channel-bill (*Scythrops Novæ-Hollandiæ*) is said to possess the same curious habit, but many species of this group build nests for themselves in the ordinary manner. Beside the typical Cuckoos (*Cuculus*) this group contains the American Cuckoos (*Coccygus*), the Anis (*Crotophaga*), the Honey-guides (*Indicator*), and other less important forms.

The second family of the *Scansores* is that of the *Picidæ*, and comprises the Woodpeckers and Wry-necks. These birds feed chiefly upon insects, and the tongue is very extensible, barbed at the point, and covered with a viscid secretion, so as to enable them to catch their prey by suddenly darting it out. The bill is strong and wedge-shaped, and the claws crooked. The tail-feathers terminate in points, and are unusually hard and stiff, assisting the bird in running up the trunks of trees. The Woodpeckers are widely distributed throughout both hemispheres, and the Wry-necks (*Yunx*) are European.

The next family is that of the Parrots (*Psittacidæ*), the largest group of the *Scansores*, comprising several hundred species. The bill in the Parrots is large and strong, and the upper mandible is considerably longer than the lower, and is hooked at its extremity (fig. 343). The bill is used as a kind of third foot in climbing, thus allowing the feet to be used in prehension. At the base of the upper mandible is a "cere," in which the nostrils are pierced. The tongue is soft and fleshy. The feet are especially adapted for climbing, some, however, of the Parrots moving about actively on the ground. The colours of the plumage are generally extremely bright and gaudy; and they live for the most part upon fruits. The *Psittacidæ* are distributed throughout the tropics, and in the southern hemisphere as far south as the 52d parallel. They are monogamous, and make their nests in holes in trees, and in the rocks. Their natural voice is harsh and grating. The true Parrots (*Psittacus*) are mostly inhabitants of tropical America, and their prevailing colour is green. Other well-known forms are African. The Cockatoos (*Plyctolophus*), the Love-birds (*Agapornis*), and the Lorikeets (*Trichoglossus*) belong to the Melanesian and Australian province. The Lories (*Lorius*) inhabit the Melanesian province. The true Macaws (*Arainæ*) are exclusively American; and the true Parrakeets (*Pezoporinæ*) are exclusively confined to the eastern hemisphere, being especially characteristic of Australia.

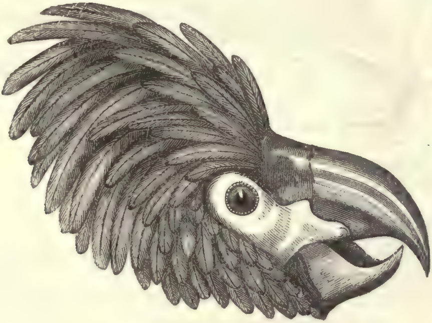

Fig. 343.—Head of Cockatoo.

Among the more remarkable of the *Psittacidæ* may be mentioned the singular "Kakapo" (*Strigops habroptilus*) of New Zealand, which makes an approach to the Owls. This curious Parrot differs from the ordinary members of the order in not being gregarious in its habits, in only being active by night, in forming burrows in the ground, in which it spends the day, and in being limited in its powers of flight. One species of Parrot (*Lophopsittacus Mauritianus*) has become extinct during the human period, and the Philip Island Parrot (*Nestor productus*), of the New Zealand province, has not been known to occur since the year 1851.

In the next family of the *Scansores* are the Toucans (*Rhamphastidæ*), characterised by having a bill which is always very large, longer than the head, and sometimes of comparatively gigantic size (fig. 344). The mandibles are, however, to a very great extent hollowed out into air-cells, so that the weight of the bill is much less than would be anticipated from its size.

The tongue is very long, notched at its side, or feathered with delicate lateral processes. The Toucans live chiefly upon fruits, and are all confined to the hotter regions of South America, frequenting the forests in considerable flocks.

The Trogons have short and weak feet, a short triangular bill, the gape bordered with strong bristles, and short wings. The plumage is soft and loose, and generally of the most gorgeous description. They inhabit the most retired recesses of the forests of the intertropical regions of both hemispheres, and show many decided points of affinity to the Goatsuckers.

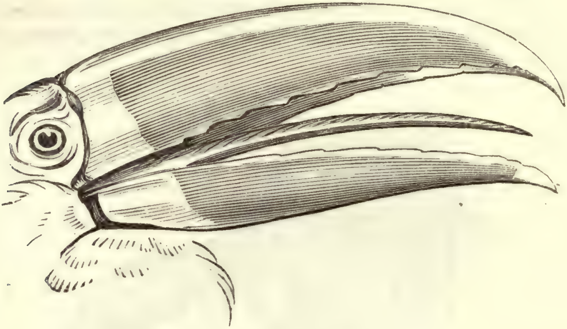

Fig. 344.—Head of Toucan.

The Barbets (*Bucconidæ*) are South American, but also occur in Africa and in the Indian province. Lastly, the Plantain-eaters or Touracos (*Musophagidæ*) are exclusively confined to Africa.

The range of the *Scansores* in *time* does not appear to be extensive, the earliest known representative of the order being from the Lower Tertiary. The Eocene beds of Wyoming have yielded remains of a Woodpecker (*Uintornis*), and Parrots, Trogons, Cuckoos, and Woodpeckers are known to have lived during the later Tertiary and Post-tertiary periods.

ORDER V. INSESSORES.—The sixth order of Birds is that of the *Insessores*, or Perchers—often spoken of as the *Passeres*, or "Passerine" Birds. They are defined by Owen as follows: "*Legs slender, short, with three toes before and one behind, the two external toes united by a very short membrane*" (fig. 345, E, F).

"The *Perchers* form the largest and by far the most numerous order of birds, but are the least easily recognisable by distinctive characters common to the whole group. Their feet, being more especially adapted to the delicate labours of nidification, have neither the webbed structure of those of the *Swimmers*, nor the robust strength and destructive talons which characterise the feet of the *Birds of Rapine*, nor yet the extended toes which enable the *Wader* to walk safely over marshy soils and tread lightly on the floating leaves of aquatic plants; but the toes are slender, flexible, and moderately elongated, with long, pointed, and slightly curved claws.

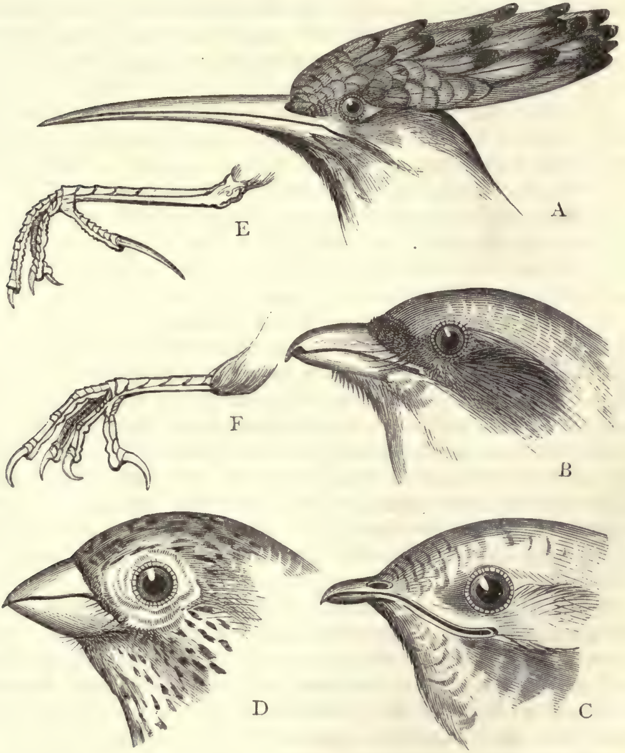

Fig. 345.—A, Head of Hoopoe (*Upupa epops*), showing the Tenuirostral type of beak. B, Head of Red-backed Shrike (*Lanius collurio*), showing the Dentirostral type of beak, C, Head of White-bellied Swift (*Cypselus melba*), showing the Fissirostral type of beak. D, Head of Corn-bunting (*Emberiza miliaria*), showing the Conirostral type of beak. E, Foot of the Yellow Wagtail (*Motacilla sulphurea*). F, Foot of a Finch (*Fringilla*).

"The Perchers in general have the females smaller and less brilliantly coloured than the males; they always live in pairs, build in trees, and display the greatest art in the construction of their nests. The young are excluded in a blind and naked state, and wholly dependent for subsistence during a certain period on parental care. The brain arrives in this order at its greatest proportionate size; the organ of voice here attains its greatest complexity, and all the characteristics of the bird, as power of flight, melody of voice, and beauty of plumage, are enjoyed in the highest perfection by one or other of the groups of this extensive and varied order."

The structure of the feet, then, gives the definition of the order, but the minor subdivisions are founded on the nature of the beak; this organ varying in form according to the nature of the food, "which may be small or young birds, carrion, insects, fruit, seeds, vegetable juices, or of a mixed kind" (Owen).

In accordance with the form of the beak, the *Insessores* have been divided into four great sections or sub-orders, known as the *Conirostres*, *Dentirostres*, *Tenuirostres*, and *Fissirostres*.

Sub-order 1. *Conirostres.*—In this section of the *Insessores* the beak is strong and on the whole conical, broad at the base and tapering with considerable rapidity to the apex (fig. 345, D). The upper mandible is not markedly toothed at its lower margin. Good examples of the conirostral type of beak are to be found in the common Sparrow, Hawfinch, or Bullfinch. The greater number of the *Conirostres* are omnivorous; the remainder are granivorous, or feed on seeds and grains. The sub-order includes the families of the Horn-bills (*Bucerotidæ*), the Starlings (*Sturnidæ*), the Crows (*Corvidæ*), the Cross-bills (*Loxiadæ*), and the Finches and Larks (*Fringillidæ*).

In the Horn-bills the conirostral shape of the beak is masked, partly by its being of very great size, and partly by the fact that above the upper mandible is placed a hollow appendage like a kind of helmet. Both the beak and the appendage above it are rendered light by the presence of numerous air-cells. The Horn-bills are exclusively confined to the warm countries of the eastern hemisphere, and are the largest of all the Insessorial birds, sometimes attaining the size of a goose; and they must be regarded as only provisionally placed in this order. They live on fruits, and make their nests in the holes of trees. The best-known species is the Rhinoceros Bird (*Buceros rhinoceros*) of India and the Indian Archipelago.

The family of the *Corvidæ*, or Crows, is an extremely extensive one, and includes a large number of very dissimilar-looking birds, all characterised by their long, strong, and compressed beaks, the tip of the upper mandible being slightly hooked and more or less notched. In this family are the Jays (*Garrulinæ*); the true Crows or *Corvinæ* (comprising the Rooks, Carrion-crows, Ravens, Jackdaws, Magpie, Chough, &c.), and the Birds of Paradise (*Paradiseidæ*). These last differ considerably from the ordinary *Corvidæ*, but can hardly be separated as a distinct family. They are amongst the most beautiful of all birds, and are entirely confined to New Guinea and the neighbouring islands. They feed upon insects and fruit, and are largely destroyed for the sake of their feathers. The natives who capture them usually cut off their legs; hence the notion formerly prevailed that the Birds of Paradise were destitute of these limbs. It is only the males which possess the brilliant plumage, the females being soberly dressed; and in accordance with this fact, it is stated that the Birds of Paradise are polygamous, being in this respect an exception to almost the entire order of the *Insessores.** "They are characterised by extraordinary developments of plumage, which are unequalled in any other family of birds. In several species large tufts of delicate, bright-coloured feathers spring from each side of the body, forming trains, fans, or shields; and the middle feathers of the train are often elongated into wires, twisted into fantastic shapes, or adorned with the most brilliant metallic tints. In another set of species, the accessory plumes spring from the head, the back, or the shoulders; whilst the intensity of colour and of metallic lustre displayed by their plumage, is not to be equalled by any other birds, except, perhaps, the Humming-birds, and is not surpassed by these." (Wallace.)

The family of the Starlings (*Sturnidæ*) is not separated from that of the Crows by any important characters. Besides our common Starlings, it includes a number of other more or less singular birds, of which the Bower-birds of Australia are perhaps the most peculiar. These curious birds have the habit of building very elaborate bowers, often very beautifully constructed and of considerable size, in which they amuse themselves and apparently make love to one another. These bowers are wholly independent of their nests, which they construct elsewhere.

The last family of the *Conirostres* is that of the *Fringillidæ*, comprising the Finches, Linnets, and Larks. In these birds the bill is stout and conical, with a sharp apex, but not having the upper mandible toothed. The toes are adapted for perching, and are provided with long and curved claws, that of the hinder toe being usually longer than the rest. They are almost all monogamous, and they build more or less elaborate nests. In this family are the true Finches (*Fringilla*), the Sparrows, (*Pyrgita*), the Linnets and Goldfinches (*Carduelis*), the Whydah Finches (*Vidua*), the Grosbeaks (*Coccothraustes*), the Bullfinches (*Pyrrhula*), and many others, but their numbers are so great that any further notice of them is impossible here. It may be mentioned, however, that the Finches of the Old World are represented in the tropical parts of America by the Tanagers (*Tanagridæ*), remarkable for their brilliant colours.

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* The Humming-birds are thought to be polygamous, and this is certainly the case with the Whydah Finch (*Vidua*).

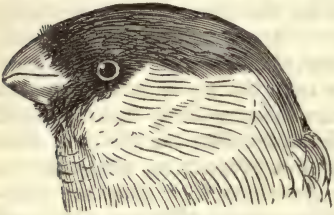

Fig. 346. — Head of the common Bullfinch (*Pyrrhula vulgaris*), showing the conirostral beak.

The only remaining members of the *Conirostres* which require notice are the Cross-bills (*Loxiadæ*), which are sometimes placed with the Finches, and sometimes considered as a separate family. In these birds the structure of the beak is so peculiar that its conirostral character is completely masked, and it has been looked upon as a deformity. Both mandibles, namely, cross one another towards the tip, giving the entire bill a most remarkable appearance. In point of fact, however, instead of being a deformity, the bill of the Cross-bills is a beautiful natural adaptation, enabling the bird with the greatest facility to tear in pieces the hard fir-cones, on the seeds of which it feeds.

Sub-order 2. *Dentirostres.*—The birds in this section are characterised by the fact that the upper mandible is provided with a distinct notch in its lower margin near the tip (fig. 345, B). They all feed chiefly upon insects. This sub-order includes the Shrikes (*Laniidæ*), the Fly-catchers (*Muscicapidæ*), the Thrushes (*Merulidæ*), the Tits (*Paridæ*), and the Warblers (*Sylviadæ*).

The *Muscicapidæ*, including the numerous species of Fly-catchers, are the most insectivorous of the *Dentirostres*. The gape is wide and bordered with bristles, and the legs are short and weak. They are mostly sedentary, catching their prey from a fixed point.

The Shrikes are highly predaceous birds, which in many respects make a close approach to the true Birds of Prey. They feed, however, mostly upon worms and insects, and only occasionally destroy small birds or mice.

The great family of the Thrushes (*Merulidæ*) comprises not only the true Thrushes, Fieldfares, and Blackbirds, but a number of exotic forms, of which the most familiar are the Orioles, so well known for their brilliant plumage and their beautifully-constructed nests.

In the *Sylviadæ*, amongst other forms, are the Wagtails (*Motacillinæ*) and the Pipits (*Anthus*), the Titmice, Robins, Hedge-sparrow, Stonechat, Redstarts, and other well-known British birds. The Titmice (*Paridæ*) are often placed in the sub-order of the *Conirostres.* The Nightingale also belongs to this family.

Sub-order 3. *Tenuirostres.*—The members of this sub-order are characterised by the possession of a long and slender beak, gradually tapering to a point (fig. 345, A). The toes are very long and slender, the hind-toe or hallux especially so. Most of the Tenuirostral birds live upon insects, and some of these present a near resemblance in many of their characters to the *Dentirostres*, but it is asserted that some live partially or wholly on the juices of flowers.

The chief families of the *Tenuirostres* are the Creepers (*Certhidæ*), the Honey-eaters (*Meliphagidæ*), the Humming-birds (*Trochilidæ*), the Sun-birds (*Promeropidæ*), and the Hoopoes (*Upupidæ*), of which only the Creepers and Humming-birds need any further notice.

The family *Certhidæ* includes several familiar British birds, such as the little brown Creeper (*Certhia familiaris*), the Nuthatch (*Sitta Europæa*), and the Wrens (*Troglodytes*). With these are a number of exotic forms, of which the singular Lyre-birds of Australia are the most remarkable.

The family of the *Trochilidæ*, or Humming-birds, includes the most fragile and brightly coloured of all the birds, some not weighing more than twenty grains when alive, and many exhibiting the most brilliant play of metallic colours. The Humming-birds are pre-eminently South American, but extend northwards as far even as the southern portions of Canada. The bill is always very long and slender, as are the toes also. The tongue is bifid and tubular, and appears to be used either to catch insects within the corollas of flowers, or to suck up the juices of the flowers themselves. The plumage of the males is always brilliant, with metallic reflections, that of the females generally sombre. The legs are short and weak, but the wings are proportionately very long, and the flight is exceedingly rapid.

The Sun-birds represent in the Old World the Humming-birds of the western hemisphere, and the Australian Honey-eaters show also many points of resemblance to the *Trochilidæ.*

Sub-order 4. *Fissirostres.*—In this sub-order of the *Insessores* the beak is short but remarkably wide in its gape (figs. 345, C, and 347), and the opening of the bill is fenced in by a number of bristles (*vibrissæ*). This arrangement is in accordance with the habits of the *Fissirostres,* the typical members of which live upon insects and take their prey upon the wing. The most typical Fissirostral birds, in fact, such as the Swallows and Goatsuckers, fly about with their mouths widely opened; and the insects which they catch in this way are prevented from escaping, partly by the bristles which border the gape, and partly by a viscid saliva which covers the tongue and inside of the mouth.

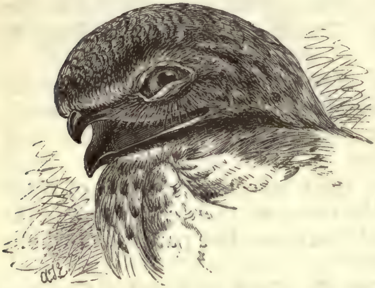
Fig. 347.—Head of Goatsucker (*Caprimulgus*), showing the fissirostral form of beak.

The group of the *Fissirostres,* with various additions (notably with that of the Humming-birds), is often raised to the rank of a distinct order (the *Volitores* of Professor Owen).

The typical *Fissirostres,* characterised by the structure of the beak, comprise three families—the Swallows and Martins (*Hirundinidæ*), the Swifts (*Cypselidæ*), and the Goatsuckers (*Caprimulgidæ*). These three families differ in many important respects from one another, but it would be inconvenient to separate them here. The Swifts, especially, are remarkable for the peculiarity that whilst the hallux is present, it is turned forwards along with the three anterior toes. The Goatsuckers, again, hunt their prey by night, and they are provided with the large eyes and thick soft plumage of all nocturnal birds. Besides the above, there remain the two families of the Kingfishers and Bee-eaters, which are generally placed amongst the *Fissirostres,* though in very many respects the arrangement appears to be an unnatural one. These families are characterised by their stronger and longer bills, and by having the external toe nearly as long as the middle one, to which it is united nearly as far as the penultimate joint. In consequence of this peculiar conformation of the toes, these families were united by Cuvier into a single group under the name of *Syndactyli.*

The *Caprimulgidæ* are intermediate between the Owls and the Passerine Birds. Their plumage is lax and soft, and they have a hawking flight. The eyes and ears are large, the feet short and weak, and the gape of enormous size and bordered by vibrissæ. Amongst the more remarkable members of the family may be mentioned the Whip-poor-will (*Antrostomus vociferus*) of North America, the More-pork (*Podargus Cuvieri*) of Australia, and the extraordinary Guacharo Bird (*Steatornis Caripensis*) of the valley of Caripe in the West Indies.

The *Hirundinidæ* have a wide gape, with few or no vibrissæ, the wings being very long and the feet short and weak. All the Swallows feed upon insects, which they catch upon the wing, and they have a cosmopolitan range.

The Swifts (*Cypselidæ*), though closely resembling the Swallows in external appearance and mode of life, have little real affinity to them. The gape is extremely wide; the wings are very long and pointed; the feet are short and weak; and the hallux is either permanently turned sideways or forwards, or can be made to assume this position at the will of the bird. The Swifts are very widely distributed in temperate and warm regions. The "edible bird's-nests" of the Chinese are made of the inspissated saliva of a Swift (*Collocalia*).

The Bee-eaters (*Meropidæ*) live upon insects, chiefly upon various species of bees and wasps; but the Kingfishers live upon small fish, which they capture by dashing into the water. The common Kingfisher (*Alcedo ispida*) is a somewhat rare native of Britain, and is perhaps the most beautiful of British birds. Some exotic Kingfishers are of large size, and one of the most remarkable of them is the Laughing Jackass (*Dacelo gigas*) of Australia, so called from its extraordinary song, resembling a prolonged hysterical laugh. A very beautiful species is the belted Kingfisher (*Ceryle alcyon*) of North America.

The Bee-eaters are found chiefly in the warmer regions of the Old World, and their place is taken in America by the Motmots (*Momotus*).

As regards their *distribution* in *time*, the *Insessores* are not known in rocks older than the Tertiary. The Eocene Slates of Glaris have yielded the Passerine *Protornis Glarisiensis;* and in the Eocene deposits of the Paris basin occur remains of the Passerine genera *Laurillardia* and *Palæogithalus.* The

Kingfishers seem to be also represented at the same period by the *Halcyornis toliapicus* of the London Clay. The Insessorial remains of the later Tertiary and Post-Tertiary deposits present no features of special interest.

ORDER VI. RAPTORES (*Aëtomorphæ*).—All the members of this order are characterised by the shape of *the bill, which is "strong, curved, sharp-edged, and sharp-pointed, often armed with a lateral tooth"* (Owen). *The upper mandible is the longest* (fig. 348, B), *and is strongly hooked at the tip. The body is very muscular; the legs are robust, short, with three toes in front and one behind, all armed with long, curved, crooked claws or talons* (fig. 348, A); *the wings are commonly pointed, and of considerable size, and the flight is usually rapid and powerful.* The Birds of Rapine are monogamous, and the female is larger than the male. They build their nests generally in lofty and inaccessible situations, and rarely lay more than four eggs, from which the young are liberated in a naked and helpless condition.

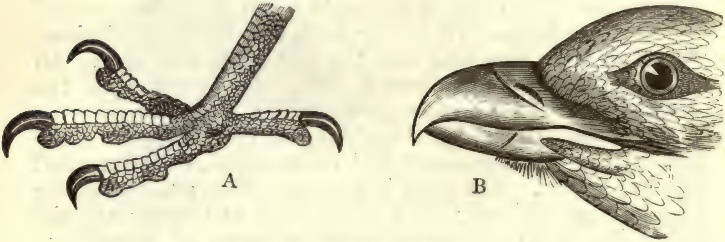

Fig. 348.—A, Foot of the Peregrine Falcon; B, Head of Buzzard.

The order *Raptores* is divided into two great sections—the *Nocturnal* Birds of Prey, which hunt by night and have the eyes directed forwards; and the *Diurnal* Raptores, which catch their prey by day, and have the eyes directed laterally.

The section of the *Nocturnal Raptores* includes the single family of the *Strigidæ*, or Owls. In these birds the eyes are large and are directed forwards. The plumage is exceedingly loose and soft, so that their flight (even when they are of large size) is almost noiseless; and it is generally spotted or barred with different shades of grey, brown, or yellow. The beak is short, strongly hooked, furnished with bristles at its base, and having the nostrils pierced in a membranous "cere" at the base of the upper mandible. The cranial bones are highly pneumatic, and the head is therefore of large size. The feathers of the face usually form an incomplete or complete "disc" or circle round each eye (fig. 349, B), and a circle of plumes is likewise placed

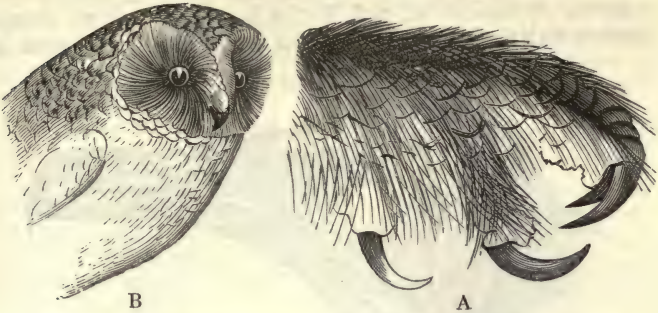

Fig. 349.—A, Foot of Tawny Owl (*Ulula stridula*); B, Head of White Owl (*Strix flammea*).

round each external meatus auditorius. Besides this auricular circle of feathers, the external meatus of the ear is likewise protected by a fold of skin. The legs are short and strong, and are furnished with four toes, all armed with strong crooked talons. The outer toe can be turned backwards, so that the foot has some resemblance to that of the *Scansores*. The tarso-metatarsus is densely feathered (fig. 349, A), and the plumes sometimes extend to the extremities of the toes. The œsophagus is not dilated into a crop; and the indigestible portions of the food are rejected by regurgitation from the stomach in the form of small pellets. The Owls hunt their prey in the twilight or on moonlight nights, occasionally by day, and they live mostly upon the lesser Mammalia and small birds, though they will also eat insects or frogs.

The section of the *Diurnal Raptores* includes the four groups of the *Falconidæ*, the *Vulturidæ*, the *Cathartidæ*, and the *Gypogeranidæ*. The eyes in this section are much smaller than in the preceding, and are placed laterally; and the plumage is not soft. As regards their power of flight, they show a decided advance upon the Nocturnal Birds of Prey. The wings are long and pointed; the sternal keel and pectoral muscles are greatly developed; and many of the members of this section exhibit a more rapid power of locomotion than is seen in any other division of the animal kingdom. The bill is long and strong, with a large "cere" at the base of the upper mandible, in which the nostrils are pierced. The tarso-metatarsus and toes are usually covered by scales, and are rarely feathered.

Lastly, the œsophagus is dilated into a capacious crop, the gizzard is thin, the intestinal cæca are rudimentary, and the intestinal canal is generally short and wide.

In the *Falconidæ* (fig. 348, B) the head and neck are always clothed with feathers, and the eyes are more or less sunk in the head, and provided with a superciliary ridge or eyebrow. It is to a great extent to the presence of this ridge that many of these birds owe their fearless and bold expresion. In this family are the Falcons, Hawks, Buzzards, Kites, Harriers, and Eagles, most of which are so well known that any description is unnecessary.

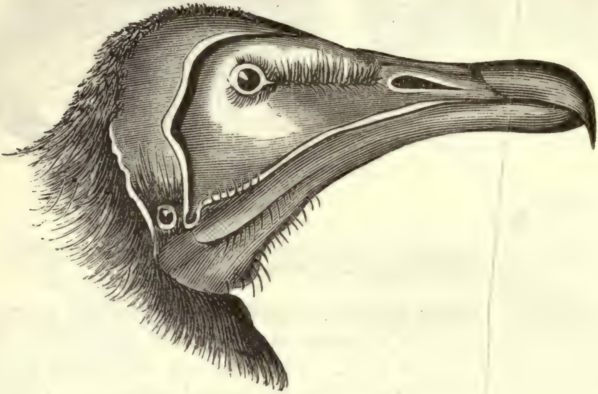

Fig. 350.—Head of Vulture (*Neophron percnopterus*).

The Old World Vultures (*Vulturidæ*), as shown by Professor Huxley, are really closely allied to the *Falconidæ* proper, from which they are hardly separable as a family. They live however, principally upon carrion, are destitute of an eyebrow, and have the head and neck frequently naked or covered only with a short down (fig. 350). In this group are the typical "Vultures" (*Vultur*, *Neophron*, &c.), and the great Bearded Vulture or Lammergeyer (*Gypaëtos barbatus*) of the mountain-ranges of the south of Europe and the west of Asia.

The American Vultures form the separate family of the *Cathartidæ*. They have no eyebrows; the head and upper part of the neck are unfeathered; the bill is not powerfully raptorial; the feet have the anterior toes partially webbed; the talons are blunt and little curved; there is no inferior larynx; and the gullet dilates into a very large crop. They all feed principally upon carrion, and are filthy and cowardly birds. The wings, however, are long and strong, and they possess great powers of flight. This group comprises the Californian Vulture (*Cathartes Californianus*) of Western North America, the King Vulture (*Sarcoramphus papa*) of tropical America, and the famous and gigantic Condor (*Sarcoramphus gryphus*) of South America.

Lastly, the family of the *Gypogeranidæ* includes only the single genus *Gypogeranus* or *Serpentarius*, including only the curious "Secretary Bird" of Africa. In this singular bird, the legs are long and slender, with an unfeathered tarso-metatarsus, thus resembling a typical Wader; whilst the wings are long and armed with blunt spurs. The Secretary-bird lives principally upon Snakes and other reptiles, which it kills by blows from its feet and wings.

As regards their *distribution* in *time*, the *Raptores* seem to make their first appearance in the Eocene Tertiary, where both sections of the order are represented, the Diurnal forms by the *Lithornis vulturinus* of the London Clay, and the Nocturnal by the *Bubo leptosteus* of the Eocene of Wyoming. Amongst the later representatives of the group may be mentioned the *Harpagornis* of the Post-Tertiary of New Zealand, a colossal Bird of prey, which was a contemporary of the Moas.

CHAPTER LXVII.

SAURORNITHES AND ODONTORNITHES.

SUB-CLASS III. SAURORNITHES.

ORDER I. SAURURÆ.—This order includes only the extinct bird, the *Archæopteryx macrura* (fig. 351), a single specimen of which—and that but a fragmentary one—has been discovered in the Lithographic Slates of Solenhofen (Upper Oolites). This extraordinary bird appears to have been about as big as a Rook; but it differs from all known birds in having two free claws belonging to the wing, and in having *a long lizard-like tail, longer than the body, and composed of separate vertebræ. The tail was destitute of any ploughshare-bone, and each vertebra carried a single pair of quills. The metacarpal bones, also, were not anchylosed together as they are in all other* *known birds, living or extinct, and two of the digits appear to have been unguiculate.*

The sub-class *Saurornithes* includes only the single order *Saururæ*, of which no other representative is known than the Jurassic *Archæopteryx*. From the presence of feathers it may be inferred that *Archæopteryx* was hot-blooded, and this character, taken along with the structure of the extremities, is sufficient to justify the reference of this unique fossil to the Birds. In the long lizard-like tail, composed of numerous free vertebræ, each of which bears a pair of tail-feathers, in the fact that the metacarpals were not anchylosed together, and in the possession of two free clawed digits to the manus, *Archæopteryx* differs from all other known birds, living or extinct. There is also some reason to believe that the jaws were furnished with teeth sunk in distinct sockets.

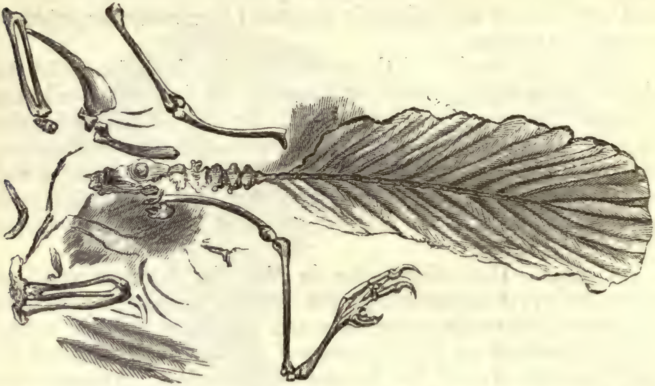

Fig. 351.—*Archæopteryx macrura*, showing tail and tail-feathers, with detached bones.

SUB-CLASS IV. ODONTORNITHES.

ORDER I. ODONTOLCÆ.—This order has been founded by Marsh for the reception of the extraordinary *Hesperornis regalis*, from the Cretaceous rocks of North America. In this wonderful fossil we have a gigantic diving-bird somewhat resembling the true "Divers" or "Loons" (*Colymbus*), but having the jaws furnished with numerous conical recurved *teeth*, sunk in a deep continuous groove (fig. 352, *b* and *d*).

The front of the upper jaw does not carry teeth, and was probably encased in a horny beak. The breast-bone is entirely destitute of a central ridge or keel, and the wings are minute and quite rudimentary; so that *Hesperornis*, unlike *Ichthyornis*, must have been wholly deprived of the power of flight, in this respect approaching the existing Penguins. The tail consists of about twelve vertebræ, of which the last three or four are amalgamated to form a flat terminal mass, there being at the same time clear indications that the tail was capable of up and down movement in a vertical plane, this probably fitting it to serve as a swimming-paddle or rudder. The vertebræ of the cervical and dorsal regions are of the ordinary ornithic type. The legs were powerfully constructed, and the feet were adapted to assist the bird in rapid motion through the water. The known remains of *Hesperornis regalis* prove it to have been a swimming and diving bird, of larger dimensions than any of the aquatic members of the class of Birds with which we are acquainted at the present day. It appears to have stood between five and six feet high, and its inability to fly is fully compensated for by the numerous adaptations of its structure to a watery life. Its teeth prove it to have been carnivorous in its habits, and it probably lived upon fishes.

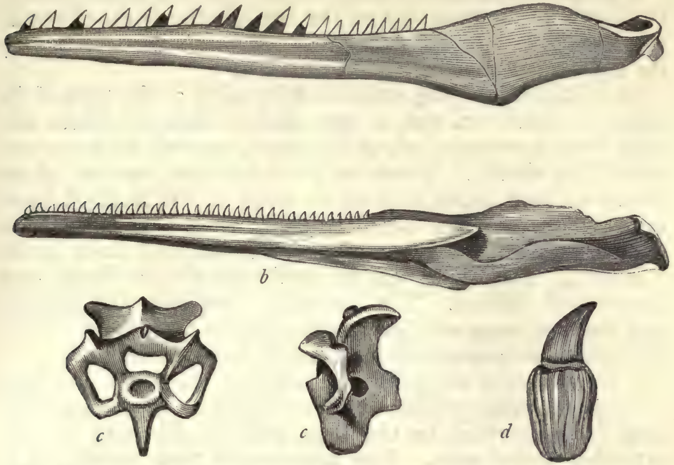

Fig. 352.—Toothed Birds (*Odontornithes*) of the Cretaceous rocks of America. *a*, Left lower jaw of *Ichthyornis dispar*, slightly enlarged; *b*, Left lower jaw of *Hesperornis regalis*, reduced to nearly one-fourth of the natural size; *c*, Cervical vertebra of *Ichthyornis dispar*, front view, twice the natural size; *c′*, Side view of the same; *d*, Tooth of *Hesperornis regalis*, enlarged to twice the natural size. (After Marsh.)

From the next order, the present is readily distinguished by the fact that *the vertebræ resemble those of recent birds, the ster-*

num is without a keel, the wings are rudimentary, and the teeth are implanted in a groove in the jaw and not in separate sockets.

ORDER II. ODONTOTORMÆ.—This order has been founded by Marsh for the reception of two remarkable birds, which he has named *Ichthyornis dispar* and *Apatornis celer*, both from the Cretaceous rocks of North America.

In *Ichthyornis dispar*, which may be taken as the type of the order, the teeth (fig. 352, *a*) were sunk in distinct sockets, and were "small, compressed, and pointed, and all of those preserved are similar. Those in the lower jaw number about twenty in each ramus, and are all more or less inclined backwards. . . . The maxillary teeth appear to have been equally numerous, and essentially the same as those in the mandible. The skull was of moderate size, and the eyes placed well forward. The lower jaws are long and slender, and the rami were not closely united at the symphysis. . . . The jaws were apparently not encased in a horny sheath.

"The scapular arch, and the bones of the wings and legs, all conform closely to the true ornithic type. The wings were large in proportion to the legs, and the humerus had an extended radial crest. The metacarpals were united, as in ordinary birds. The bones of the posterior extremities resemble those of swimming birds. The vertebræ (see fig. 352, *c* and *c'*) were all biconcave, the concavities at each end of the centra being distinct and nearly alike. Whether the tail was elongated cannot at present be determined; but the last vertebra of the sacrum was unusually large.

"The bird was fully adult, and about as large as a pigeon. With the exception of the skull, the bones do not appear to have been pneumatic, though most of them are hollow. The species was carnivorous, and probably aquatic." (Marsh.)

Apatornis agrees with *Ichthyornis* in most of the above characters, but the structure of its jaws is not fully known. It follows from the above that the order *Odontotormæ* is characterised by the possession of *distinct teeth sunk in separate sockets in the jaw and not in a continuous groove, by the fact that the vertebræ are biconcave, and by the possession of a carinate sternum and well-developed wings.*

LITERATURE.

[In addition to many of the works mentioned in the list of treatises relating to the Vertebrata in general, the following are some of the more important sources of information as to recent and fossil Birds :—]

1. Article "Aves." Owen. 'Todd's Cyclopædia of Anat. and Phys.' 1836.

2. Article "Birds." Newton and Parker. 'Encyclopædia Britannica.' 9th edt. 1875.
3. "Genera of Birds." G. R. Gray. 1844-49.
4. "System der Pterylographie." Nitzsch and H. Burmeister. 1840.
5. "Pterylography." Nitzsch. Translated by Sclater. 'Ray. Soc.' 1867.
6. "Manuel d'Ornithologie." Temminck. 1820.
7. "Natural History and Classification of Birds." Swainson. 1836.
8. "On the Classification and Distribution of the Alectoromorphæ and Heteromorphæ." Huxley. 'Proc. Zool. Soc.' 1868.
9. "On the Classification of Birds." Huxley. 'Proc. Zool. Soc.' 1867.
10. "Aves." Selenka. 'Bronn's Klassen und Ordnungen des Thierreichs.' 1869.
11. "Elements of Embryology." Foster and Balfour. 1874.
12. "On the Osteology of Gallinaceous Birds and Tinamous." Parker. 'Trans. Zool. Soc.' 1866.
13. "On the Skull of the Ostrich." Parker. 'Phil. Trans.' 1866.
14. "Essai sur l'appareil locomoteur des Oiseaux." Alix. 1874.
15. "Animal Locomotion." Pettigrew. 1873.
16. "Recherches Anatomiques et Paléontologiques pour servir à l'histoire des Oiseaux fossiles de la France." Alphonse Milne-Edwards. 1867-77.
17. "British Fossil Mammals and Birds." Owen. 1846.
18. "Memoir on the Apteryx." Owen. 'Proc. Zool. Soc.' 1842.
19. "Anatomy of the Southern Apteryx." Owen. 'Trans. Zool. Soc.' 1838 and 1842.
20. "On Dinornis." Owen. 'Trans. Zool. Soc.' 1839-64.
21. "Osteologia Avium." Eyton. 1861-64.
22. "Osteology of the Dodo." Owen. 'Trans. Zool. Soc.' 1867.
23. "The Dodo and its kindred." Strickland and Melville. 1848.
24. "Archæopteryx macrura." Owen. 'Phil. Trans.' 1863.
25. "On the Odontornithes or Birds with Teeth." Marsh. 'Geol. Magazine.' 1876.
26. "Geographical Distribution of Animals." Wallace. 1876.
27. "General History of Birds." Latham. 1821-28.
28. "Anatomie und Naturgeschichte der Vögel." Tiedemann. 1810-14.
29. "Histoire Naturelle, générale et particulière, des Oiseaux." Buffon. Ed. by Sonnini. An. xiv. (Eng. Translation by Smellie. 1793.)
30. "History of British Birds." Bewick. 6th ed. 1826.
31. "History of British Birds." Macgillivray. 1839-41.
32. "History of British Birds." Yarrell.
33. "Catalogue of Birds in the British Museum." Bowdler Sharpe. 1874, 1875, 1877.
34. "Birds of Europe." Gould. 1832-37.
35. "Birds of Australia." Gould. 1840-48.
36. "Monograph of the Trochilidæ." Gould.
37. "Monograph of the Rhamphastidæ." Gould. 1833-35.
38. "Illustrations of Ornithology." Jardine and Selby. 1825-39.
39. "Monograph of the Anatidæ." Eyton. 1838.
40. "Monograph of the Alcedinidæ." Sharpe. 1871.
41. "Iconographie Ornithologique." Des Murs. 1849.
42. "Birds of America." Audubon. 1826.
43. "Birds of America." Audubon. (Abridged from the larger work.) 1840-44.
44. "American Ornithology." Wilson. 1808-14.
45. "Catalogue of North American Birds." Baird. 1859.

46. "Key to North American Birds." Coues. 1872.
47. "Fauna Boreali Americana." Richardson. (The Birds by Swainson.) 1831.
48. "Distribution and Migration of American Birds." Baird. 'Amer. Journ. Sci. and Arts.' 1866.
49. "Manual of the Ornithology of the United States and Canada." Nuttall. 2d ed. 1840.
50. "Birds of India." Jerdon. 1862-64.

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DIVISION III.—MAMMALIA.

CHAPTER LXVIII.

GENERAL CHARACTERS OF THE MAMMALIA.

THE last and highest class of the *Vertebrata*, that of the *Mammalia*, may be shortly defined as including *Vertebrate animals in which some part or other of the integument is always provided with hairs at some time of life; and the young are nourished, for a longer or shorter time, by means of a special fluid—the milk—secreted by special glands—the mammary glands.* These two characters are of themselves sufficient broadly to separate the Mammals from all other classes of the Vertebrate sub-kingdom. In addition, however, to these two leading peculiarities, the Mammals exhibit the following other characters of scarcely less importance:—

1. The skull articulates with the vertebral column by means of a double articulation, the occipital bone carrying two condyles, in place of the single condyle of the Reptiles and Birds.

2. The lower jaw or mandible consists of two halves or rami, united anteriorly by a symphysis, but not necessarily anchylosed; but these are each composed of a single piece, instead of being complex and consisting of several pieces, as in the Reptiles and Birds. Further, the lower jaw always articulates directly with the squamosal element of the skull, and is never united to an os quadratum, as in the *Sauropsida.*

3. The two hemispheres of the cerebral mass, or brain proper, are united together by a more or less extensively developed "corpus callosum" or commissure.

4. The heart consists—as in Birds—of four cavities or chambers, two auricles and two ventricles. The right and left sides of the heart are completely separated from one another, and there is no communication between the pulmonary and systemic circulations. The red blood-corpuscles are non-nucleated, and, with the exception of those of the *Camelidæ*,

they are circular biconcave discs. There is only one aorta—the left—which turns over the left bronchus. and not over the right, as it does in Birds.

5. The cavities of the thorax and abdomen are completely separated from one another by a muscular partition—the diaphragm or midriff.

6. The respiratory organs are in the form of two lungs placed in the thorax, but none of the bronchi end in air-receptacles, distributed through the body, as in Birds.

7. The embryo mammal is invariably enveloped in an amnion, and an allantois is never wanting. The allantois, however, either disappears at an early period of life, or it develops the structure known as the "placenta." The placenta is a vascular organ which serves as a means of communication between the parent and the fœtus, but it will be noticed more particularly hereafter.

8. In no Mammal do the visceral arches and clefts of the embryo ever carry branchiæ, as they do in the fishes and Amphibians.

These are the essential characters which distinguish the *Mammalia* as a class, but it will be necessary to consider these, and some other points, in a more detailed manner.

In the first place, with regard to the osteology of the Mammals, the following points should be noticed:—

With the exception of the Whales and Dolphins (*Cetacea*), and the Dugongs and Manatees (*Sirenia*), the vertebral column is divisible into the same regions as in man—namely, into a cervical, dorsal, lumbar, sacral, and caudal or coccygeal region (see fig. 241). In the *Cetacea* and *Sirenia* the dorsal region of the spine is followed by a number of vertebræ which compose the hinder extremity of the body, but which cannot be separated into lumbar, sacral, and caudal vertebræ.

In spite of the great difference which is observable in the length of the neck in different Mammals, the number of vertebræ in the cervical region is extraordinarily constant, being almost invariably seven, as in man. In this respect there is no difference between the Whale and the Giraffe. The only exceptions to this law are the Manatees (*Manatus*) which have but six cervical vertebræ; the three-toed Sloth (*Bradypus tridactylus*), which is commonly regarded as possessing nine, though competent anatomists would refer the posterior two of these to the dorsal region; and one of the two-toed Sloths (*Cholœpus Hoffmanni*), which has only six cervical vertebræ.

The dorsal vertebræ are mostly thirteen in number, but they vary from ten to twenty-four. In man there are twelve, in one of the Armadillos only ten, and in the two-toed Sloths and the *Hyrax* the maximum is attained. The lumbar vertebræ are usually six or seven in number, rarely fewer than four. In Man they are five in number, and they are reduced to two in the two-toed Sloth, one of the Ant-eaters, and the Duck-mole.

The first vertebra, or atlas, always bears two articular cavities for the reception of the two condyles of the occipital bone; and the second vertebra, or axis, usually has an "odontoid" process, on which the head rotates. In the true Whales, however, in which the cervical vertebræ are anchylosed together to a greater or less extent, and the neck is immovable, the odontoid process is also wanting.

In almost all Mammals the spinous processes of the dorsal vertebræ are very largely developed for the attachment of the structure which is known as the *ligamentum nuchæ.* This is a great band of elastic fibrous tissue, which is attached in front to the occipital bone and spinous processes of the cervical vertebræ, and which relieves the muscles of the task of supporting the head in those Mammals which progress with the body in a horizontal position. The development of the *ligamentum nuchæ* is consequently, as a rule, proportionate to the size of the head and the length of the neck. In Whales no such apparatus is necessary, owing to the fixation of the cervical vertebræ by anchylosis; and in Man, who walks erect, the *ligamentum nuchæ* can hardly be said to exist as a distinct structure, being merely represented by a band of fascia.

The number of lumbar and sacral vertebræ, as we have seen, varies in different Mammals; but ordinarily some of the vertebræ are anchylosed into a single bone, and have the iliac bones abutting against them, thus constituting the "sacrum" of human anatomists. In the *Cetacea* and *Sirenia*, in which the hind-limbs are wanting, and the pelvis rudimentary, there is no "sacrum."

The thoracic cavity or chest in Mammals is always enclosed by a series of ribs, the number of which varies with that of the dorsal vertebræ. In most cases each rib articulates by its head with the bodies of *two* vertebræ, and by its tubercle with the transverse process of one of these vertebræ (the lower one). In the *Monotremata* (*e.g.*, the Duck-mole), the ribs articulate with the body of the vertebra only; and in the Whales, the hindermost of the ribs, or all of them, articulate with the transverse processes only, and not with the centra at all.

There are usually no bony pieces uniting the ribs with the sternum or breast-bone in front, as in Birds; but the so-called "sternal ribs" of *Aves* are represented by the "costal cartilages" of the Mammals. In some cases, however, the cartilages of the ribs do become ossified and constitute sternal ribs. Sometimes, as in the Armadillos, there is a joint between the vertebral ribs and sternal ribs. More rarely, as in the *Monotremes* (fig. 357, D), an intermediate piece is found between the vertebral and costal portions of the rib. Only the anterior ribs reach the sternum, and these are called the "true" ribs; the posterior ribs, which fall short of the breast-bone, being known as the "false" ribs.

The sternum or breast-bone (fig. 353) is formed of several pieces placed one behind the other, but usually anchylosed together to form a single bone. It is placed upon the ventral surface of the body, and is united with the vertebral column by the ribs and their cartilages. It is generally a long and narrow bone, but in the *Cetacea* it is broad. It is only in some burrowing animals (such as the Moles) and in the true flying Mammals (the Bats), that the sternum is provided with any ridge or keel for the attachment of the pectoral muscles, as it is in Birds. The sternum is primitively composed of three pieces, an anterior piece or *præsternum*, a middle piece or *mesosternum*, and a posterior piece or *xiphisternum*. The

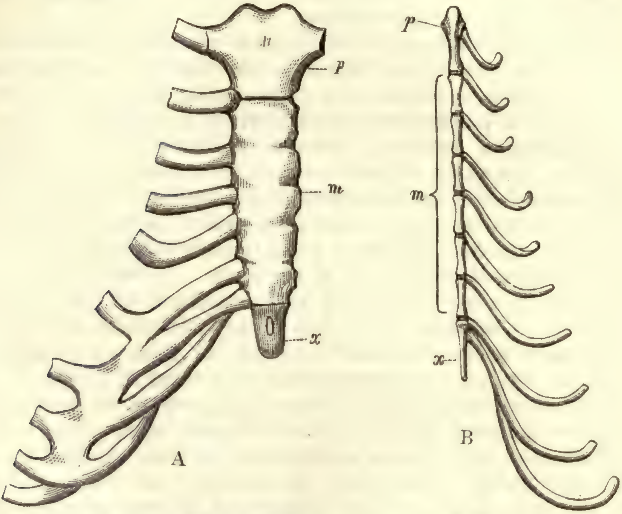

Fig. 353.—A, Sternum of Man, with the costal cartilages. B, Sternum and costal cartilages of the Dog : *p* Præsternum ; *m* Mesosternum ; *x* Xiphisternum.

præsternum is the "manubrium sterni" of human anatomy, and is the portion of the sternum which lies in front of the attachment of the second pair of ribs. All the other ribs are connected with the mesosternum. The *xiphisternum* is the "xiphoid cartilage" of human anatomy, and it commonly remains throughout life more or less unossified. In the Monotremes there is a T-shaped bone above or in front of the præsternum, but this is to be regarded as belonging to the shoulder-girdle, and as representing the "episternum" or "interclavicle" of the Reptiles.

The normal number of limbs in the *Mammalia* is four, two anterior and two posterior; and hence they are often spoken of as "quadrupeds," though all the limbs are not universally present, and other animals have four limbs as well. The anterior limbs are not known to be wanting in any Mammal, but the posterior limbs are absent in the *Cetacea* and *Sirenia*.

As regards the structure of the anterior limb, the chief points to be noticed concern the means by which it is connected with the trunk. The scapula or shoulder-blade is never absent, and it is in the form of a broad flat bone (rarely long and narrow), applied to the outer aspect of the ribs, and much more developed than in the Birds. The coracoid bone, which forms such a marked feature in the scapular arch of *Aves*, is fused with the scapula, and only articulates with the sternum in the Duckmole and Echidna (*Monotremata*). In all other Mammals the coracoid forms merely a process of the scapula, and does not reach the top of the breast-bone. The collar-bones or clavicles never unite in any Mammal to form a "furculum," as in Birds; but in the Monotremes they unite with an "interclavicle," placed in front of the sternum. The clavicles, in point of fact, are not present in a well-developed form in any Mammals except in those which use the anterior limbs in flight, in digging, or in prehension. The *Cetacea*, the Hoofed Quadrupeds (*Ungulata*) and some of the *Edentata*, have no clavicles. Most of the *Carnivora* and some Rodents possess a clavicle, but this is imperfect, and does not articulate with the top of the sternum. The Insectivorous Mammals, many of the Rodents, the Bats, and all the *Quadrumana*, have (with Man) a perfect clavicle articulating with the anterior end of the sternum.

The humerus, or long bone of the upper arm (*brachium*), is never wanting, but is extremely short in the Whales, in which the anterior limbs are converted into swimming-paddles. In many Mammals, as in the Monkeys, and *Felidæ* (constituting the most typical group of the *Carnivora*), the median nerve and brachial or ulnar artery are protected on their way down the arm by a canal placed a little above the elbow, and formed by a process—the "supra-condyloid" process—which is sometimes present in man as an abnormality.

In the fore-arm of all Mammals the ulna and radius are recognisable, but they are not necessarily distinct; and the radius, as being the bone which mainly supports the hand, is the only one which is always well developed, the ulna being often rudimentary. In the *Cetacea* the ulna and radius are anchylosed together; and in most of the Hoofed Quadrupeds they are anchylosed towards their distal extremities. In the flying Mammals or Bats the ulna is hardly recognisable, being reduced to its upper third and fused with the radius. The fore-arm attains its greatest perfection in man, in whom the radius can rotate upon the ulna, so as to allow the back of the hand to be placed upwards or downwards, these movements being known respectively as "pronation" and "supination." In the Monkeys only is there any approach to this power of rotation.

The fore-arm is succeeded by the small bones which compose the wrist or "carpus." These are eight in number in Man, but vary in different Mammals from five to eleven.

The metacarpus in Man and in most Mammals consists of five cylindrical bones, articulating proximally with the carpus, and distally with the phalanges of the fingers. The most remarkable modification of this normal state of things occurs in the Ruminants and in the Horse. In the Ruminants, in which the foot is cleft, and consists of two perfect toes only, there are two metacarpal bones in the embryo; but these are anchylosed together in the adult, and form a single mass which is known as the "canon-bone" (fig. 354, *c*). In the Horse, in which the foot consists of no more than a single digit, there is only a single metacarpal bone, on each side of which are two little bony spines — the so-called "splint-bones" — which are attached superiorly to the carpus, and are to be regarded as rudimentary metacarpals. In most of the other Ungulates there are at least three metacarpals, and in the elephants there are five.

The normal number of digits is five, but they vary from one to five. The middle finger is the longest, and most persistent of the digits of the fore-limb; and in the Horse it is the only one which is left (fig. 355). The thumb is very frequently absent. In the Ruminants there are only two fingers which are functionally useful, these carrying the hoofs. In most Ruminants, however, there are two rudimentary and functionally useless digits in addition.

Normally each digit has three phalanges, except the thumb, which has only two. In the Whales and Dolphins (*Cetacea*), in which the anterior limbs form swimming-paddles, very like those of the *Ichthyosaurus* and *Plesiosaurus*, the phalanges are considerably increased in number as they are in those Reptiles. In all the Mammalia, too, except the *Cetacea*, it is the rule that the terminal phalanx in each digit should carry a nail, claw, or hoof.

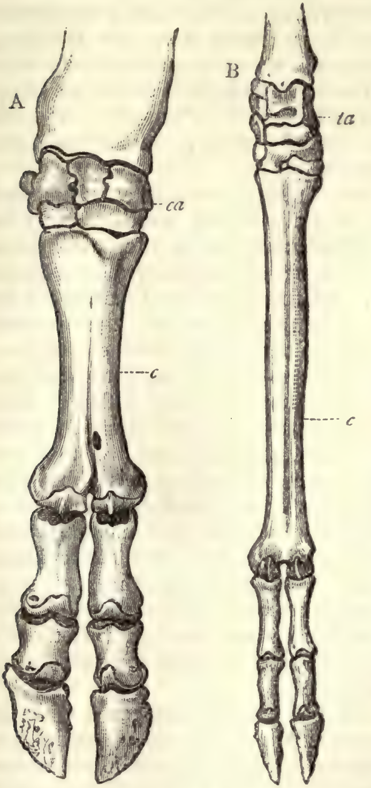

Fig. 354.—A, Fore-leg of Ox (*Bos taurus*). B, Hind-leg of Stag (*Cervus elaphus*). *ca* Carpus; *ta* Tarsus; *c* "Canon-bone," composed of the united metacarpals or metatarsals of the 3d and 4th digits.

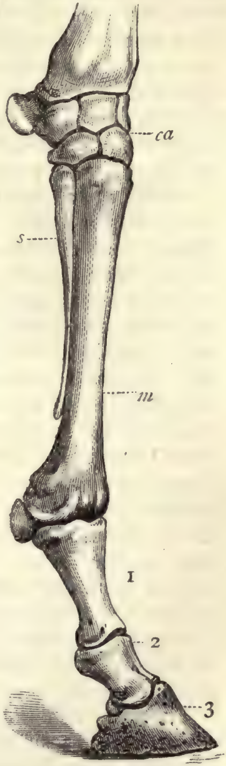

Fig. 355.—Fore-leg of Horse. *ca* Carpus; *m* Metacarpal of the third digit; *s* "Splint-bone," or rudimentary metacarpal; 1, First phalanx or "great pastern;" 2, Second phalanx or "small pastern;" 3, Third phalanx or "coffin-bone."

The power of opposing the thumb to the other digits of the hand is found only in Man, and in a considerable number of the *Quadrumana*, but never so perfectly developed as in Man. In Man only does this power attain its full perfection, and it constitutes one of the most striking of the merely *anatomical* peculiarities by which Man is separated from the Monkeys. As, however, this feature is purely adaptive, and is really to be regarded as of extremely small physiological value, we ought to learn from this that the difference between Man and the *Quadrumana* is to be sought in the mental powers of each, and not in any merely structural character.

Whilst the anterior limbs are never absent in any Mammal, the posterior limbs are occasionally wholly wanting, as in the *Cetacea* and *Sirenia* (in *Halitherium*, an extinct Sirenian, a rudimentary femur exists). Generally speaking, however, the posterior limbs are present, and the pelvic arch has much the same structure as in Man. The two halves of the pelvis—the ossa innominata—consist each of three pieces in the embryo—viz., the ilium, ischium, and pubes—which meet to form the cup-shaped cavity known as the "acetabulum," with which the head of the thigh-bone articulates. In the adult Mammal these three bones are anchylosed together, and the two ossa innominata unite in front by means of a symphysis pubis, constituted either by a cartilaginous union (synchondrosis), or by merely ligamentous attachment. In some Mammals, however, such as the Mole, and many of the Bats, the pubic bones remain disunited during life. As a rule, also, the ossa innominata are firmly united with the vertebral column. In the Cetaceans, in which the hind-limbs are wanting, and there is no sacrum, the innominate bones are rudimentary, and are not attached in any way to the spine.

The only other bones which are ever connected with the pelvis are two small bones which are directed upwards from the brim of the pelvic cavity in Marsupials and Monotremes. These are the so-called "marsupial bones," regarded generally as not forming parts of the skeleton properly so called, but as being ossifications of the internal tendons of the "external oblique" muscles of the abdomen (fig. 360).

In those Mammals which possess hind-limbs, the normal composition of the member is of the following parts: 1. A thigh-bone or femur; 2. Two bones forming the shank, and known as the tibia and fibula; 3. A number of small bones constituting the ankle or tarsus; 4. The "root" of the foot, made up of the "metatarsus;" 5. The phalanges of the toes (see fig. 243).

The thigh-bone or femur articulates with the pelvis, usually at a very open angle. In Man it is distinguished by being the longest bone of the body, and by having the axis of its shaft nearly parallel to that of the vertebral column. In most Mammals the femur is relatively shorter, and the axis of its shaft deviates considerably from that of the spine, being sometimes at right angles, or even at an acute angle.

Of the bones of the leg proper (*crus*) the tibia corresponds to the radius in the fore-limb, as shown by its carrying the tarsus; and the fibula is the representative of the ulna. The articulation between the tibia and fibula on the one hand, and the femur on the other, constitutes the "knee-joint," which is usually defended in front by the "knee-pan" or patella, a large sesamoid bone developed in the tendons of the great extensor muscles of the thigh. The patella is of small size in the *Carnivora*, but does not appear to be wanting in any except in some of the Marsupials. In many cases the tibia and fibula are anchylosed towards their distal extremities. In the Horse the fibula has much the same character as in Birds, being a long splint-like bone which only extends about half-way down the tibia. In the Ruminants the reverse of this obtains, the upper half of the fibula being absent, and only the lower half present.

The tibia articulates with the tarsus, consisting in Man of seven bones, but varying in different Mammals from four to nine.

The foot, or *pes*, consists normally of five toes, connected with the tarsus by means of five metatarsal bones, which closely resemble the metacarpals. In the Ruminants there are two principal metatarsals, and these are anchylosed in the adult, and carry two toes. In the Horse there is only one complete metatarsal supporting a single toe. As a rule, the number of digits in the hind-limb or foot is the same as that in the fore-limb or hand; but this is not always the case. In the Lions, Tigers, Cats, and Dogs, the posterior limb carries only four toes, the innermost toe or hallux being wanting. In the *Quadrumana*, again, all the five toes are generally present, but the four outer toes are much longer than in Man, and the hallux is shorter than the other toes, and often opposable to them, so that the foot forms a kind of posterior hand. The hallux is also not uncommonly opposable in other cases.

The cranial bones are invariably connected with one another by sutures, and in no other examples than the Monotremes are these sutures obliterated in the adult. The differences of opinion which are entertained as to the fundamental structure of the skull are so enormous, that it will be best not to attempt here any detailed description of the skull of the Mammalia, more especially as there is as yet no universal agreement even as to the nomenclature to be employed. It is sufficient to remember that the skull is composed of a series of bony segments, which are often regarded as modified vertebræ. The occipital bone carries two condyles for articulation with the first cervical vertebra. The lower jaw is composed of two halves or rami, which are distinct from one another in the embryo, and may or may not be anchylosed together in the adult. However this may be, in no Mammal is the ramus of the lower jaw composed of several pieces, as it is in Birds and Reptiles, nor does it articulate with the skull by the intervention of an os quadratum. On the other hand, each ramus of the lower jaw in the Mammals is composed of only a single piece, and articulates with the squamosal element of the skull, or, in other words, with the squamous portion of the temporal bone.

Teeth are present in the great majority of Mammals; but they are only present in the embryo of the whalebone Whales, and are entirely absent in the genera *Echidna*, *Manis*, and *Myrmecophaga*. In the Duck-mole (*Ornithorhynchus*) the so-called teeth are horny, and the same was the case in the extinct *Rhytina* amongst the *Sirenia*. In all other Mammals the teeth have their ordinary structure of dentine, enamel, and crusta petrosa, these elements being variously disposed in different cases, the enamel being occasionally wanting. In no Mammals are the teeth ever anchylosed with the jaw; and in all, the teeth are implanted into distinct sockets or alveoli, which, however, are very imperfect in some of the Cetacea.

Many Mammals have only a single set of teeth throughout life, and these are termed by Owen "monophyodont." In most cases, however, the first set of teeth—called the "milk" or "deciduous" teeth—is replaced in the course of growth by a second set of "permanent" teeth. The deciduous and permanent sets of teeth do not necessarily correspond to one another; but no Mammal has ever *more* than these two sets. The Mammals with two sets of teeth are called by Owen "diphyodont."

In Man and many other Mammals the teeth are divisible into four distinct groups, which differ from one another in position, appearance, and function; and which are known respectively as the *incisors*, *canines*, *præmolars*, and *molars* (fig. 356). "Those teeth which are implanted in the præmaxillary bones, and in the corresponding part of the lower jaw, are called 'incisors,' whatever be their shape or size.

The tooth in the maxillary bone which is situated at or near to the suture with the præmaxillary, is the 'canine,' as is also that tooth in the lower jaw which, in opposing it, passes in front of its crown when the mouth is closed. The other teeth of the first set are the 'deciduous molars;' the teeth which displace and succeed them vertically are the 'præmolars;' the more posterior teeth, which are not displaced by vertical successors, are the 'molars' properly so called" (Owen). The deciduous dentition, therefore, of a diphyodont Mammal consists of only three kinds of teeth—incisors, canines, and molars. The incisor and canine teeth of the deciduous set are replaced by the teeth which bear the same names in the permanent set. The deciduous "molars," however, are replaced by the permanent "præmolars," and the "molars" of the permanent set of teeth are not represented in the deciduous series, only existing once, and not being replaced by successors. It has, however, been shown that in some diphyodont Mammals there may be certain of the anterior maxillary teeth in the permanent dentition, which are not represented by any predecessors in the deciduous series. This is the case, for example, with the first præmolar of the Dog.

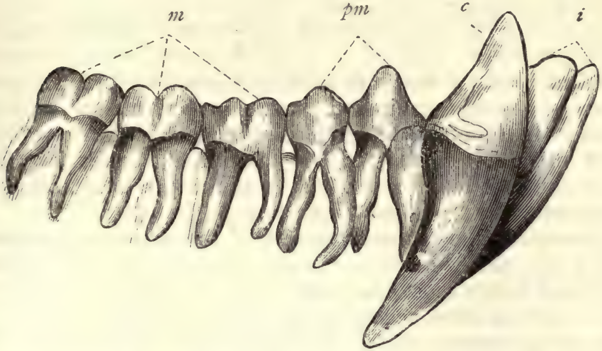

Fig. 356.—Teeth of the right side of the lower jaw of the Chimpanzee (after Owen). *i* Incisors; *c* Canine tooth; *pm* Præmolars; *m* Molars.

All these four kinds of teeth are not necessarily present in all Mammals, and, as will be afterwards seen, the characters of the teeth are amongst the most important of the distinctions by which the Mammalian orders are separated from one another. The variations which exist in the number of teeth in different Mammals are usually expressed by a "dental formula," which presents the "dentition" of both jaws in a condensed and easily recognised form.

According to Owen, the typical permanent dentition of a diphyodont Mammal would be expressed by the following formula:—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{4-4};\quad m\,\frac{3-3}{3-3}=44.$$

The four kinds of teeth are indicated in such a formula by the letters—incisors *i*, canines *c*, præmolars *pm*, molars *m*. The numbers in the upper line indicate the teeth in the upper jaw, those in the lower line stand for those in the lower jaw; and the number of teeth on each side of the jaw is indicated by the short dashes between the figures.

As regards the digestive system of the *Mammalia*, salivary glands are present in all except the true *Cetacea*. The alimentary canal has in most cases essentially the same structure as in man; and the same accessory glands are present—namely, the liver and pancreas. Some very remarkable modifications occur in the structure of the stomach and in the termination of the intestine; but these will be noticed in speaking of the orders in which they occur. The cavity of the abdomen is always separated from that of the thorax by a complete muscular partition—the diaphragm—as is the case in no other Vertebrate animals. The abdomen contains the greater portion of the alimentary canal, the liver, spleen, pancreas, kidneys, and other organs. The thorax mainly holds the heart and lungs.

The heart is contained in a serous bag, the pericardium, and consists (as in Birds) of two auricles and two ventricles. The effete and deoxygenated blood is returned from the tissues by the veins, and is conducted by the two venæ cavæ to the right side of the heart into the right auricle. From the right auricle it passes into the right ventricle, whence it is propelled through the pulmonary artery to the lungs. Having been submitted to the action of the air, the blood, now arterialised, is carried by the pulmonary veins to the left auricle, and thence into the left ventricle. From the left ventricle the aerated blood is driven through the aorta and systemic vessels to all parts of the body. In Mammals, therefore, as in Birds, the pulmonary and systemic circulations are altogether distinct and separate from one another. The two sides of the heart—except in the fœtus and as an abnormality in adults—have no communication with one another except by means of the capillaries.

The red blood-corpuscles are never nucleated, and in all except the *Camelidæ* (in which they are oval) they are circular and discoid.

The lungs of Mammals differ from those of Birds in being freely suspended in the thoracic cavity, the greater part of which they fill, and in being enclosed freely in a serous sac (*pleura*) which envelops each lung. The lungs are minutely cellular throughout, and the bronchi never open on the surface of the lung into a series of air-receptacles communicating with one another, and placed in different parts of the body, as is the case in Birds.

There is no "inferior larynx," in any Mammal, and the upper aperture of the true larynx is always protected by an epiglottis.

The kidneys in Mammals are situated in the lumbar region, and exhibit a division of their substance into cortical and medullary portions.

There are two ovaries in the Mammals, and the oviducts are known as the "Fallopian tubes." Each oviduct dilates on its way to the surface into a uterine cavity, which opens into the vagina. In the Monotremes and Marsupials this primitive condition is retained throughout life, the uterus remaining double, and opening by two apertures into the cloaca or vagina. In most cases this condition is so far modified in the adult, that the two uteri have coalesced inferiorly, so as to have only a single opening into the vagina, whilst they separate into two horns or "cornua" superiorly. Only in the Monkeys and in Man have the two uteri completely coalesced to form a completely single cavity, into the "fundus" of which the Fallopian tubes open. In male Mammals there are always two testes present. In many Mammals the testes are permanently retained in the abdominal cavity, and there is no scrotum. This is the case in the Monotremes, the Elephants, all the *Cetacea*, and many of the *Edentata*. Mostly, however, the testes at an early period of life are transferred from the abdomen to a pouch of integument called the "scrotum." Usually the scrotum is placed beneath the pubic arch and behind the penis, but this position is reversed in the Marsupials.

Mammary glands are present in all Mammals, and they are regarded by Huxley as an extreme modification of the cutaneous sebaceous glands. In the male Mammals the mammary glands are present, but, under all ordinary circumstances, they remain functionally useless and undeveloped. Considerable differences obtain as to the number and position of the mammary glands in different cases; but they are always placed on the inferior surface of the body, and their ducts in the great majority of cases open collectively upon a common elevation —the "teat" or "nipple." In the *Monotremata*, however, there are no nipples, the ducts of the mammary glands opening either into a pouch of the integument (*Echidna*) or upon a flat surface (*Ornithorhynchus*).

The young Mammal is nourished for a longer or shorter time by the milk secreted by the mammary glands of the mother. In ordinary cases the milk is obtained by voluntary suction on the part of the young animal; but in the Marsupials the young are at first unable to suck for themselves, and the milk is forced out of the gland by the contractions of a special muscle.

The nervous system of Mammals is chiefly remarkable for the great proportionate development of the cerebral mass as compared with the size of the spinal cord. In the higher Mammals, again, the hemispheres of the cerebrum are much more largely developed proportionately than the remaining parts of the brain. The brain of the Mammals is chiefly distinguished from that of the lower *Vertebrata* by the fact that the two hemispheres of the cerebellum are united by a transverse commissure — the *pons Varolii;* and the hemispheres of the cerebrum are connected by a great commissure—the *corpus callosum*—which is, however, of small size in the lower *Mammalia.*

The senses, as a rule, attain great perfection in the Mammals; and the only sense which appears to be ever entirely wanting is that of vision. The sclerotic coat of the eye is never supported by a ring of bony plates as in Birds and many Reptiles. As a rule, in addition to the upper and lower eyelids there is a third perpendicular lid—the *membrana nictitans* —but this is wanting or quite rudimentary in Man and in the Monkeys.

An external ear or *concha* for collecting the vibrations of sound is usually present, but is wanting in the *Cetacea*, many of the Seals, and in some other cases.

The integument is furnished over a greater or less portion of its surface with the epidermic appendages known as "hairs."

These are developed, much as feathers are, upon little eminences or papillæ of the dermis, but they do not split up in the process of development as feathers do. In the *Manis* or Scaly Ant-eater the epidermic appendages are in the form of horny scales, and not uncommonly they are developed into long spines, as in the *Echidna*, Porcupine, and Hedgehog. The only apparent exception to the universal presence of hairs in some part or other of the skin of all Mammals is constituted by the *Cetacea*, the great majority of which are without hairs in the adult state. Some, however, occasionally possess a few bristles in the neighbourhood of the mouth even when fully grown. And the Dolphins, which are totally hairless when adult, exhibit tufts of hair on the muzzle in the fœtal state.

The claws, hoofs, and nails of Mammals, and the horny sheaths of the horns of the Cavicorn Ruminants, are also of the nature of epidermic growths.

Lastly, the Armadillos are remarkable for having plates of bone developed in the dermis over a greater or smaller portion of the surface.

Distribution of Mammalia in Time.—As a matter of course, the remains of Mammals are scanty, and occupy but a small space in the geological record, since the greater number of the *Mammalia* are terrestrial, and the greater number of the stratified fossiliferous deposits are marine. The Mammals, too, are the most highly organised of the entire sub-kingdom of the *Vertebrata;* and therefore, in obedience to the well-known law of succession, they ought to make their appearance upon the globe at a later period than any of the lower classes of the *Vertebrata.* Such, in point of fact, is to a great extent the case; and if the geological record were perfect, the law would doubtless be carried out to its full extent.

It is in the upper portion of the Triassic rocks—that is to say, not long after the commencement of the Mesozoic or Secondary epoch—that Mammals for the first time make their appearance; three or four species being now known in a zone of rocks placed at the summit of the Trias, just where this formation begins to pass into the Lias. The earliest of these—the oldest known of all the Mammals—appears at the upper part of the Upper Trias (Keuper) and also at its very summit (Penarth Beds), and has been described under the name of *Microlestes antiquus.* The nearest ally of *Microlestes* amongst existing Mammals would seem to be the Marsupial and insectivorous *Myrmecobius*, or Banded Ant-eater of Australia. As only the teeth, however, of *Microlestes* have hitherto been discovered, it is impossible to decide positively whether this primeval Mammal was Marsupial or Placental.

The next traces of Mammals occur in the Stonesfield Slate (Lower Oolites), and here four species, all of small size, are known to occur. Most of these were Marsupial, but it is possible that one was placental. They form the genera *Amphilestes*, *Amphitherium*, *Phascolotherium*, and *Stereognathus.* After the Stonesfield Slate another interval succeeds, in which no Mammalian remains have hitherto been found; but in the fresh-water formation of the Middle Purbeck—at the top, namely, of the Oolitic series—as many as fourteen small Mammals have been discovered. These constitute the genera *Plagiaulax*, *Spalacotherium*, *Triconodon*, and *Galestes*. In the Jurassic rocks of North America, as in those of Europe, small Mammals (belonging to the Marsupials, and referable to the family of the *Didelphidæ*) have been discovered. Another gap then follows, no Mammal having hitherto been discovered in any portion of the Cretaceous series (with doubtful exceptions).

Leaving the Mesozoic and entering upon the Kainozoic period, remains of Mammals are never absent from any of the geological formations. From the base of the Eocene rocks up to the present day remains of Mammals commonly occur, constantly increasing in number and importance, till we arrive at the fauna now in existence upon the globe.

The more important forms of fossil Mammals will be spoken of in treating of the separate Mammalian orders.

CLASSIFICATION OF THE MAMMALIA.—Whilst there exists little divergence of opinion as to the *orders* into which the *Mammalia* may be divided, different authorities adopt different views as to the great primary divisions of the class. Here it will be sufficient to mention two modes of subdividing the *Mammalia*, of which the first will be accepted as sufficient for practical purposes.

I. The *Mammalia* may be divided into two great primary divisions, according as the structure known as the "placenta" is present or absent. The "placenta" or "afterbirth" is a highly vascular organ which is developed upon the exterior of the envelopes of the fœtus, and which is so closely connected with the inner wall of the uterus as to allow of an interchange of material between the blood of the embryo and that of the mother.* The "Placental" Mammals are thus enabled to carry their young for a much longer period than are the "Implacental" Mammals, and hence the young animal in the former is born in a much more perfectly developed condition than in the latter. The sub-class "Implacentalia," in which there is no placenta, comprises only the orders of the *Mono-*

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* No traces of vascular prominences comparable to the Mammalian placenta occur in any animals below the rank of Mammals, except in some Sharks and some Ascidians. In the Sharks, however, the vascular eminences are developed from the umbilical vesicle, and not, as in Mammals, from the allantois.

tremata and *Marsupialia*. The sub-class *Placentalia*, in which a placenta is present, comprises all the other orders of *Mammalia*.

II. The *Mammalia* may be divided as follows into three primary divisions according to the structure of the reproductive organs. This arrangement was proposed by De Blainville, and is accepted by Huxley, Rolleston, Flower, and other distinguished authorities:—

a. *Ornithodelphia*, characterised by the fact that the uterine enlargements of the oviducts do not coalesce, even in their inferior portion, to form a common uterine cavity, but open separately as in the Birds and Reptiles. Furthermore, the two uteri open, not into a distinct vagina, but into a cloacal cavity, into which the rectum and ureters also discharge themselves; so that the condition of parts is very much the same as it is in Birds.

This division includes only the Duck-mole (*Ornithorhynchus*) and the Porcupine Ant-eaters (*Echidna*), forming collectively the single order of the *Monotremata*.

b. *Didelphia*, characterised by the fact that the uterine dilatations of the oviducts continue distinct throughout life, opening into two distinct vaginæ, which in turn open into a urogenital canal, which is distinct from the rectum, though embraced by the same sphincter muscle.

This sub-class contains the *Marsupialia*, such as the Kangaroos, Opossums, Wombats, &c., most of which are almost entirely confined to Australia. They have many other characters in common which will be spoken of hereafter.

III. *Monodelphia*, characterised by the fact that the uterine enlargements of the oviducts coalesce to a greater or less extent to form a single uterine cavity, which, however, generally shows its true composition by being divided superiorly into two cornua. The uterus opens again into a single vagina, which is always distinct from the rectum. This sub-class corresponds with the division of the "Placental" Mammals, and includes all the *Mammalia* except the Monotremes and Marsupials.

NON-PLACENTAL MAMMALS.

CHAPTER LXIX.

MONOTREMATA AND MARSUPIALIA.

Order I. Monotremata.—The first and lowest order of the *Mammalia* is that of the *Monotremata*, constituting by itself the division *Ornithodelphia*, and containing only two genera, both belonging to Australia—namely, the Duck-mole (*Ornithorhynchus*) and the Porcupine Ant-eater (*Echidna*).

The order is distinguished by the following characters:—*The intestine opens into a "cloaca," which receives also the products of the urinary and generative organs, which discharge themselves into a urogenital canal*—the condition of parts being very much the same as in Birds. *The jaws are either wholly destitute of teeth* (Echidna) *or are furnished with four horny plates which act as teeth* (Ornithorhynchus). *The pectoral arch has some highly bird-like characters, the most important of these being the extension of the coracoid bones to the anterior end of the sternum. An interclavicle is also present. The females possess no marsupial pouch, but the pelvis is furnished with the so-called "marsupial bones," being special ossifications of the internal tendons of the external oblique muscles of the abdomen.* The testes of the male are abdominal throughout life, and there is therefore no scrotum, whilst the vasa deferentia open into the cloaca. The corpus callosum is very small, and has been asserted to be altogether wanting. There are no external ears. *The mammary glands have no nipples, and their ducts open either into a kind of integumentary pouch* (Echidna) *or simply on a flat surface* (Ornithorhynchus). *The young are said to be destitute of a placenta, or, in other words, no vascular connection is established between the fœtus and the mother.* The feet have five toes each, armed with claws, and the males carry perforated spurs on the back of the tarsus (attached to a supplementary tarsal bone).

The order *Monotremata* includes only the two genera *Orni-*

thorhynchus and *Echidna* (or *Tachyglossus*)—the one represented by a single species (*O. paradoxus* or *anatinus*), and the other by four species (*E. hystrix*, *E. setosa*, *E. Lawesi*, and *E. Bruijnii*). All are exclusively confined to the Australian province.

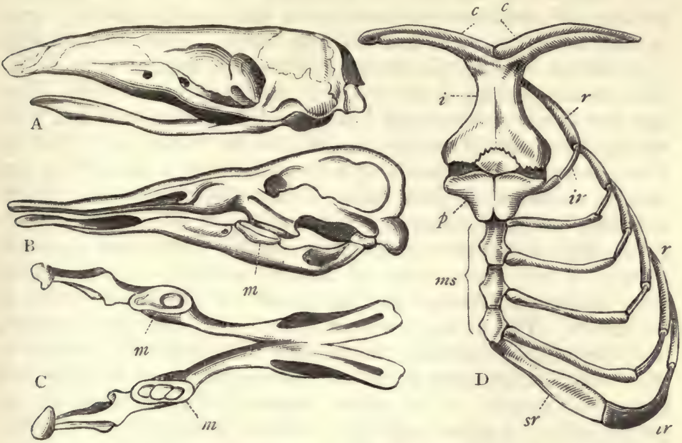

Fig. 357.—Osteology of Monotremes. A, Skull of *Echidna hystrix*. B, Side view of the skull of *Ornithorhynchus anatinus*, and C, lower jaw of the same, viewed from above, showing the horny dental plates (*m*). D, Sternum and adjacent parts of the skeleton of a young *Ornithorhynchus*: *c c* Clavicles; *i* Interclavicle; *p* Præsternum; *ms*, Mesosternum; *r r* Vertebral ribs; *ir* Intermediate ribs; *sr* Sternal ribs. (A, B, and C are after Giebel; D is after Flower.)

The *Ornithorhynchus* or Duck-mole is one of the most extraordinary of Mammals. The body (fig. 358) resembles that of a mole or small otter, and is covered with a close, short, brown fur. The tail is broad and flattened. The jaws are

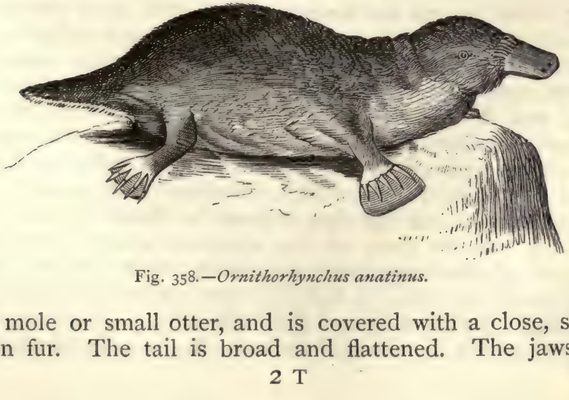

Fig. 358.—*Ornithorhynchus anatinus.*

produced to form a beak just like that of a duck in appearance; hence the name of "Duck-billed animal," often applied to it. The margins of the jaw are sheathed with horn, and are furnished with transverse horny plates, two in each jaw (fig. 357, B and C): but there are no true teeth. The sternum (fig. 357, D) is of five pieces, and there are sternal ribs. The nostrils are placed at the apex of the upper mandible. The legs are short, and the feet have five toes each, furnished with strong claws, which enable the animal to burrow with facility. The toes are also united by a membrane or web, so that the animal swims with great ease. The *Ornithorhynchus* is exclusively found in Australia, ranging as far north as Queensland, and inhabits streams and ponds. Its food consists chiefly, if not exclusively, of insects, and the animal makes very extensive burrows in the banks of the rivers which it frequents. The young are born quite blind, and nearly naked, and the method in which they obtain milk from the mother is somewhat obscure, as there are no nipples, nor is there any marsupial pouch. It is certain, however, that the beak of the young animal is extremely different from what it is in the adult condition. The young animal is totally hairless, the mandibles are soft and flexible, the tongue is not placed far back in the mouth (as it is in the adult), and the eye is at first covered by the skin.

The genus *Echidna* (*Tachyglossus*) is represented by four species—viz., *E. hystrix*, *E. setosa*, *E. Lawesi*, and *E. Bruijnii*, the first being Australian, and the second Tasmanian, whilst the two last occur in New Guinea. The *Echidna hystrix* is the best-known species, and in some external respects is not unlike a large hedgehog, having the back covered with strong spines, interspersed with a general coating of bristly hairs. The snout has not the form of a duck's bill, as in the *Ornithorhynchus*, but the two jaws are greatly elongated, and are enclosed in a continuous skin till close upon their extremities, where there is a small aperture for the protrusion of a very long and flexible tongue. The jaws (fig. 357, A) are wholly devoid of teeth or anything in the place of teeth; and the nostrils are placed at the extremity of the cylindrical snout. The feet have five toes each, furnished with strong curved digging-claws, but the toes are not webbed. There are no nipples, but the ducts of the mammary glands open at the bottom of two integumentary pouches, which are said to be sufficiently capacious to hold the young when first born. The *Echidna hystrix* measures from fifteen to eighteen inches in length, and is a nocturnal animal. It lives in burrows and feeds upon insects, which it catches by protruding its long and sticky tongue.

As regards the distribution of the *Monotremes* in *time*, no fossil remains referable to the order have ever been discovered, with the exception of a gigantic *Echidna*, recorded by Mr Krefft as occurring in the Post-tertiary deposits of Australia.

ORDER II. MARSUPIALIA.—The order *Marsupialia* constitutes by itself the sub-class *Didelphia*, and forms with the *Monotremata* the division of the Non-placental Mammals. With the single exception of the genus *Didelphys*, which is American, all the *Marsupialia* belong to the Melanesian province; that is to say, they all belong to Australia, Van Diemen's Land, New Guinea, and some of the neighbouring islands.*

The following are the characters which distinguish the order:—

The skull is composed of distinct cranial bones united by sutures, and they all possess true teeth; whilst the angle of the lower jaw is almost always inflected. The pectoral arch has the same form as in the higher Mammals, and the coracoid no longer reaches the anterior end of the sternum. All possess the so-called "marsupial bones," or cartilages, attached to the brim of the pelvis. The corpus callosum is very small, and has been asserted to be absent. The young Marsupials are born in a very imperfect condition, of very small size, and at a stage when their development has proceeded to a very limited degree only. (In the Kangaroo the period of gestation is only thirty-nine days, and in the *Didelphidæ* it is only fifteen or seventeen days.) *There is no placenta or vascular communication between the mother and fœtus, parturition taking place before any necessity arises for such an arrangement. As the young are born in such an imperfect state of development, special arrangements are required to secure their existence. When born, they are therefore, in the great majority of cases, transferred by the mother to a*

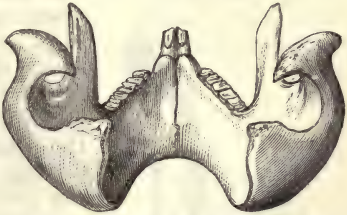

Fig. 359.—Lower jaw of the Wombat, viewed from behind, showing the strongly inflected angles of the jaw.

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* One Kangaroo (*Macropus Bruijnii*) is found in the Indian Archipelago, along with five Phalangers, which differ from the Australian forms in having the tail partially or entirely naked or scaly. There are also Tree-kangaroos, and the curious *Cuscus*, distinguished by a prehensile tail, large eyes, and slow progression.

peculiar pouch formed by a folding of the integument of the abdomen. This pouch is known as the "marsupium," and gives the name to the order. Within the marsupium are contained the nipples, which are of great length. Being for some time after their birth extremely feeble, and unable to perform the act of suction, the young within the pouch are nourished involuntarily, the mammary glands being provided with special muscles which force the milk into the mouths of the young; while the windpipe is prolonged up to the posterior nares, where it is embraced by the soft palate, so that the food passes on each side of the trachea, and there is no risk of suffocation. At a later stage the young can suckle by their own exertions, and they leave the pouch and return to it at will. In a few forms there is no complete marsupium as above described; but the structure of the nipples is the same, and the young are carried about by the mother, adhering to the lengthy teats.

The so-called "marsupial bones" (fig. 360) doubtless serve to support the marsupial pouch and its contained young, but this cannot be their sole function, since they occur in the male Marsupials and also in the Monotremes, in which there is no pouch. It is believed by Owen that the function of the marsupial bones is to assist in the action of the mammæ and testes, serving respectively as a fulcrum for the muscle spread over the mammary gland and for the cremaster.

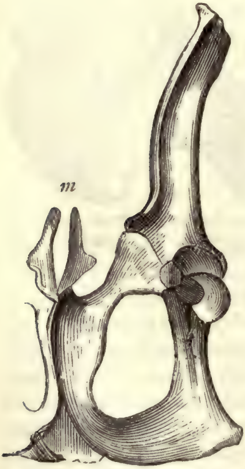

Fig. 360.—One side of the pelvis of a Kangaroo, showing the "marsupial bones" (*m*). (After Owen.)

The oviducts open into vaginal tubes which open into a urogenital canal; but this does not open into a "cloaca," though embraced by a sphincter muscle common to it and to the rectum. In other words, the vagina is separated wholly or in great part into two distinct tubes, but these open apart from the intestine. The testes are not abdominal throughout life as in the Monotremes, but are lodged in a scrotum. This, however, is placed in front of the penis, and not beneath the pubic arch as in most Mammals. From this unusual position of the scrotum, it is regarded by Owen as being the same structure as the marsupial pouch of the female, turned inside out.

Though they form an extremely natural order, sharply separated from all the rest of the Mammals, the Marsupials form a large and varied group. In fact, this order, from being the almost exclusive possessor of a continent as large as Australia, has to discharge in the economy of nature functions which are elsewhere discharged by several orders.

The *Marsupialia* are divided by Owen into the two primary sections of the *Diprotodontia* and *Polyprotodontia*, comprising the following subordinate divisions:—

(A.) DIPROTODONTIA. — Lower incisors two in number; canines rudimentary or wanting; molars mostly with broad crushing crowns.

a. Rhizophaga.—In this section is the well-known Australian animal the Wombat (*Phascolomys fossor*), often called by the colonists the "badger." The Wombat is a stout, heavy animal, which attains a length of from two to three feet. The legs are very short and stout, and the animal burrows with ease by means of strong, curved digging-claws, with which the fore-feet are furnished. The tail in the Wombat is quite rudimentary, and the whole body is clothed with a brown woolly hair. In its dentition (fig. 361) the Wombat presents a curious resemblance to the herbivorous Rodents. There are two incisors in each jaw, and these are long and rootless, growing from permanent pulps. There are no canines, so that the incisors and præmolars are separated by a considerable space. The dental formula is—

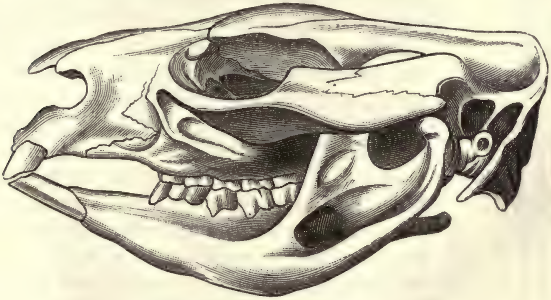

Fig. 361.—Skull of Wombat. (After Giebel.)

$$i\,\frac{1-1}{1-1};\quad c\,\frac{0-0}{0-0};\quad pm\,\frac{1-1}{1-1};\; m\,\frac{4-4}{4-4} = 24.$$

The præmolars and molars agree with the incisors in growing from permanent pulps, in which respect the Wombat differs from all the other Marsupials, and agrees with the herbivorous Rodents, with those *Edentata* which have teeth, and with the extinct *Toxodon* (Owen).

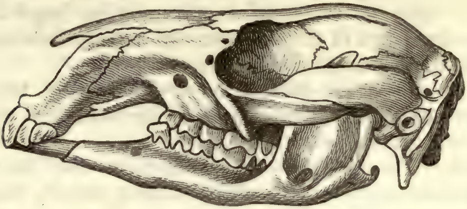
Fig. 362.—Skull of *Macropus Bennetti*. (After Giebel.)

The Wombat is a nocturnal animal, and feeds chiefly upon roots and grass; and it is found in both Australia and Van Diemen's Land.

b. Poephaga.—In this section are the Kangaroos (*Macropodidæ*) and the Kangaroo-rats or Potoroos (*Hypsiprymnus*), all strictly phytophagous. The Kangaroos are distinguished by the disproportionate length of the hind-limbs, and disproportionate development of the posterior portion of the body as compared with the fore-limbs and fore-part of the body. The hind-legs are exceedingly long and strong, and the feet are much elongated —the whole sole being applied to the ground. The hind-feet (fig. 363) have four toes each, of which the central one (the 4th toe) is by far the largest, and the two inner toes (the 2d and 3d toes) are very small, and are united by a common integument. The hallux is wanting altogether. The tail is also extremely long and strong, and is of great assistance to the animal when standing upright upon the hind-limbs. From the length and strength of the hind-limbs and hind-feet, the Kangaroos are enabled to effect extraordinarily long and continuous bounds. In fact, leaping is the ordinary mode of progression in the typical Kangaroos; and when walking upon all fours their locomotion is slow and ungraceful. The anterior extremity of the body is very dimin-

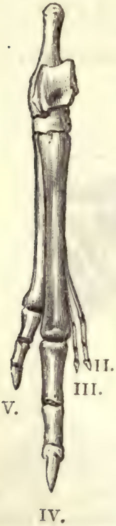

Fig. 363.—Hind-foot of *Macropus Bennetti*. (After Flower).

utive as compared with the posterior, and the fore-limbs are quite small, but have five well-developed toes armed with strong nails. The head is small, with large ears, and the dental formula is—

$$i\,\frac{3-3}{1-1};\quad c\,\frac{0-0}{0-0};\quad pm\,\frac{1-1}{1-1};\quad m\,\frac{4-4}{4-4} = 28.$$

There are therefore six upper incisors, two lower incisors (the latter horizontal, fig. 362), and no functional canines (though rudimentary upper canines are present in the young of some of the Kangaroos, at any rate). The stomach is complex, and sacculated. The Kangaroos are all herbivorous, and mostly live, either scattered or gregariously, on the great grassy plains of Australia. The "Tree-kangaroos," however, (constituting the genus *Dendrolagus*) live mostly in trees; and in adaptation to this mode of life, the fore-legs are nearly as long and strong as the hind-legs, the tail is not used as a support, and the claws are long, curved and pointed, while small upper canines are present. They are natives of New Guinea. The "Rock-kangaroos" form the genus *Petrogale*, and inhabit the mountainous regions of North-western Australia.

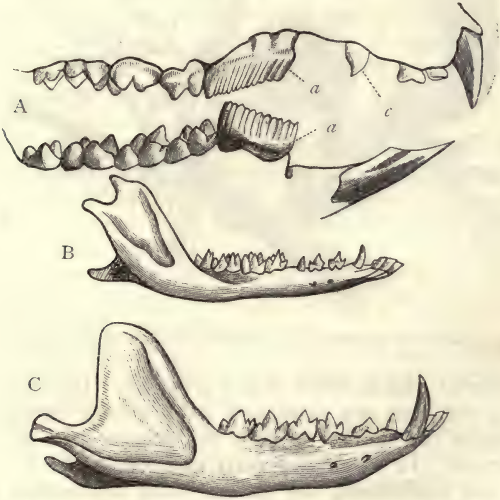

Fig. 364.—A, Dentition of a herbivorous Marsupial (*Hypsiprymnus cuniculus*), showing the upper canine (*c*) and the great grooved first præmolar (*a a*); B, Lower jaw of an entomophagous Marsupial (*Perameles obesula*); C, Lower jaw of a predatory Marsupial (*Dasyurus ursinus*). (After Giebel and Waterhouse.)

The Kangaroo-rats (*Hypsiprymnus*) differ from the true Kangaroos chiefly in their smaller size, and in the presence of well-developed upper canines (fig. 364, A), and in having scaly tails. They are diminutive nocturnal animals, and they live mostly upon roots.

c. Carpophaga.—Intermediate between the Kangaroos and the typical members of the present section (the Phalangers) is the *Phascolarctos*—the "native sloth" or "bear" of the Australian colonists, and the "koala" of the natives (fig. 365). This curious animal is about two feet in length, having a stout body, covered with a dense bluish-grey fur. The tail is wanting; and the feet are furnished with strong curved claws, which enable the animal to pass the greater part of its existence in trees. In this it is greatly assisted by the fact that all the feet are prehensile, the hallux being opposable, and the digits of the fore-limb divided into two sets, the thumb and index-finger being opposable to the other fingers. The dental formula is—

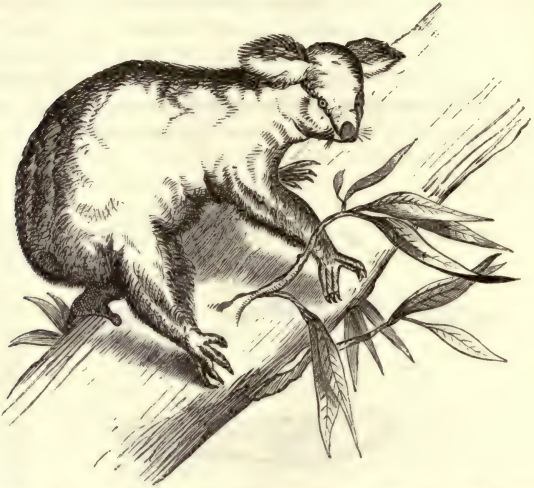

Fig. 365.—Koala or Kangaroo-bear (*Phascolarctos cinereus*) (After Gould.)

$$i\,\frac{3-3}{1-1};\quad c\,\frac{1-1}{0-0};\quad pm\,\frac{1-1}{1-1};\ m\,\frac{4-4}{4-4} = 30.$$

The koala is a slow animal which feeds on the foliage of the trees in which it spends its existence.

The typical group of the carpophagous Marsupials is that of the *Phalangistidæ* or Phalangers, so called because the second and third digits of the hind-feet are joined together almost to their extremities. The family includes a number of small Marsupials, fitted for an arboreal existence, to which end the hallux is opposable and nail-less, whilst the four remaining toes of the hind-feet have long curved claws. The tail, too, is generally very long, and its tip is usually prehensile. The Phalangers are all small nocturnal animals which live upon fruits and other vegetable food. The best known of them is the Australian Opossum or Vulpine Phalanger (*Phalangista vulpina*), which must not be confounded with the true or American Opossums, which belong to another section of the *Marsupialia*. The Phalangers, namely, are distinguished from the Opossums properly so called, amongst other characters, by their dentition, the canine teeth being always very small and functionally useless in the lower jaw, and sometimes in the upper jaw as well. The *Phalangista vulpina* is nocturnal and arboreal in its habits, and its flesh is esteemed a great delicacy by the native Australians, with whom opossum-hunting is a favourite pursuit.

The flying Phalangers or *Petauri* are closely allied to the true Phalangers, but differ in not having a prehensile tail, and in having a fold of skin extending on each side between the sides of the body and the hind and fore limbs. By the help of these lateral membranes the *Petauri* can take extensive leaps from tree to tree; but though called "flying" Phalangers, they have no power of flight properly so called. They are beautiful little animals, nocturnal in their habits, and having the body clothed with a soft and delicate fur.

(B.) POLYPROTODONTIA.—Lower incisors more than two in number; canines more or less well-developed; molars cuspidate or with sectorial crowns.

d. Entomophaga.—In this section the jaws are always furnished with canine teeth, but these are not of very large size, and the animals composing the section are therefore not highly predaceous, but "prey, for the most part, on the smaller and weaker classes of invertebrate animals." In this section are the Bandicoots (*Peramelidæ*), the American Opossums (*Didelphidæ*), and the Banded Ant-eater (*Myrmecobius*).

The Bandicoots * (*Peramelidæ*) are small Australian animals, which appear to fill the place of the Hedgehogs, Shrew-mice, and other small *Insectivora* of the Old World. The molars are cuspidate, and canines are present (fig. 364, B). The dental formula is—

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* The name "Bandicoot" properly belongs to the Great Rat (*Mus giganteus*) of India.

$$i\,\frac{5-5}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{4-4}{4-4} = 48.$$

The hind-limbs in the Bandicoots are considerable longer than the fore-limbs, and their progression is therefore by a series of bounds. The fore-limbs have really five toes each, but only the central three of these are well developed, the outermost and innermost digits being rudimentary. The three functional toes are armed with long strong claws, with which the Bandicoots burrow with great ease. The marsupial pouch—and this is a singular point—opens backwards instead of forwards. In the nearly-allied genus *Chæropus*, also from Australia, the fore-foot has only two functional digits (the 2d and 3d), the 1st and 5th digits being wanting, and the 4th being rudimentary; while the 4th digit of the hind-foot is the only functional toe.

The second family of this section—namely, the true Opossums or *Didelphidæ*—is remarkable in being the only group of the whole order which occurs out of the Australian province. The *Didelphidæ*, namely, are exclusively found in North and South America, where they are known as "Opossums." A considerable number of species is known, but they are mostly of small size, the largest measuring not more than from two to three feet, inclusive of the tail. The Virginian Opossum (*Didelphys Virginiana*) is the only member of the family which is found in North America, and it was the earliest Marsupial known to science; its place in South America being taken by the widely-distributed *Didelphys D'Azaræ*. Most of the Opossums are carnivorous, feeding upon small quadrupeds and birds, but they also eat insects, and sometimes even fruit. One species (*Didelphys cancrivora*) lives chiefly upon Crabs; and the Yapock (*Cheironectes*) has webbed feet, and leads a semi-aquatic life. All the *Didelphidæ* have the hallux nail-less and opposable to the other toes, so as to convert the hind-feet into prehensile hands, and all have a more or less perfectly prehensile tail, these being adaptations to an arboreal life. The marsupial pouch is sometimes not present in a complete form, but is merely represented by cutaneous folds of the abdomen concealing the nipples. In the *Didelphys dorsigera*, in which this peculiarity obtains, the young soon leave the nipples, and are then carried about on the back of the mother, to whom they cling by twining their prehensile tails round hers. The dentition of the Opossums (fig. 366) is remarkable for the great number of the incisor teeth, the dental formula being—

$$i\,\frac{5-5}{4-4};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{4-4}{4-4} = 50.$$

The canines are well developed, and the crowns of the molars are cuspidate.

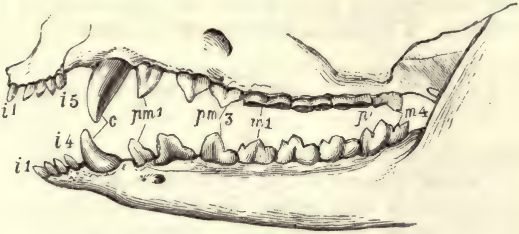

Fig. 366.—Dentition of Opossum (*Didelphys*).

The Banded Ant-eater (*Myrmecobius fasciatus*) is a small but extremely elegant little animal, which inhabits Western and Southern Australia, and lives upon insects (fig. 367). The tail is bushy, and differs from that of the *Didelphidæ* in not being prehensile. The fore-feet have five toes armed with claws; the hind-feet have only four toes. The *Myrmecobius* is remarkable for the extraordinary number of molar teeth, in which it exceeds any existing Marsupial, and is only surpassed by some of the Armadillos. The dental formula is—

$$i\,\frac{4-4}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{6-6}{6-6} = 54.$$

e. Sarcophaga.—This is the last section of the existing Marsupials, and includes a number of predaceous and rapacious forms, which fill the place held elsewhere by the true *Carnivora.* They are distinguished by the fact that the intestine is destitute of a cæcum, and by their strictly carnivorous dentition, the canines being strong, long, and pointed, whilst the molars and præmolars have cutting edges furnished with three cusps (fig. 364, C). The best-known species of this section are the *Thylacinus cynocephalus* and the *Dasyurus ursinus.* The former of these is the largest of the rapacious Marsupials, being about as big as a shepherd's dog. It is a native of Van Diemen's Land, and is known to the colonists as the "hyæna." Its head is very large, and the back exhibits several transverse black bands. The marsupial bones are peculiar in being represented only by permanent cartilages, and the marsupium opens backward. It lives in caverns and amongst the rocks in the wildest parts of the colony, and its numbers have been very much reduced by the constant war waged upon it by the settlers. The *Dasyurus ursinus* is also a native of Van Diemen's Land, where it is known as the "native devil." Though smaller than the Thylacine, the *Dasyurus* is extremely ferocious, and is capable of committing great havoc amongst animals even as large as sheep. The dental formula of *Dasyurus* is—

$$i\,\frac{4-4}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{2-2}{2-2};\quad m\,\frac{4-4}{4-4} = 42.$$

The præmolars and molars are remarkable in the fact that they, all of them, possess sharp, serrated, cutting edges.

As regards their *distribution* in *time*, the Marsupials are probably the oldest of Mammals hitherto discovered; but owing to the detached and fragmentary condition of almost all Mammalian remains—consisting mostly of the ramus of the lower jaw, or of separate teeth—it is not possible to state this with absolute certainty. The *Microlestes* of the Trias, the oldest, or nearly the oldest, of the Mammals, known only by its molar teeth (fig. 369), was *probably* a Marsupial; but the evidence upon this point is not conclusive. In the Triassic rocks of America, also, perhaps at a lower horizon than that at which *Microlestes* occurs in Europe, has been found the jaw of

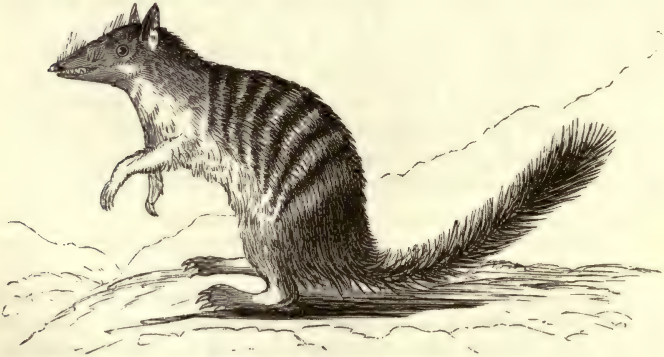

Fig. 367.—*Myrmecobius fasciatus.*

a small Mammal, which is probably Marsupial, and has been named *Dromatherium* (fig. 368).

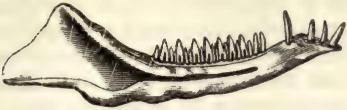

Fig. 368.—Lower jaw of *Dromatherium sylvestre.* Trias, North Carolina. (After Emmons.)

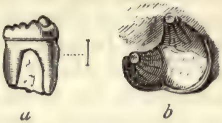

Fig. 369.—*a* Molar tooth of *Microlestes antiquus*, magnified; *b* Crown of the same, magnified still further. Trias, Germany.

In the next mammaliferous horizon, however—namely, that of the Stonesfield Slate in the Lower Oolites—there is no doubt but that some of the Mammalian remains, if not all, belong to small Marsupials (fig. 370). From this horizon the two genera, *Phascolotherium* and *Amphitherium* are almost certainly referable to the *Marsupialia;* the latter seeming to be most nearly related to the living *Myrmecobius*, whilst the former finds its nearest living ally in the Opossums of America. The *Stereognathus* of the Stonesfield Slate is in a doubtful position. It may have been Marsupial; but, upon the whole, Professor Owen is inclined to believe that it was placental, hoofed, and herbivorous.

In the middle Purbeck beds (Upper Oolite), where fourteen species of Mammals are known to exist, it is probable that all were Marsupial. All the Purbeck Mammalia were of small size, the largest being no bigger than a polecat or hedgehog. They form the genera *Plagiaulax*, *Triconodon*, and *Galestes*, of which *Plagiaulax* is believed to be most nearly allied to the living Kangaroo-rat (*Hypsiprymnus*) of Australia.

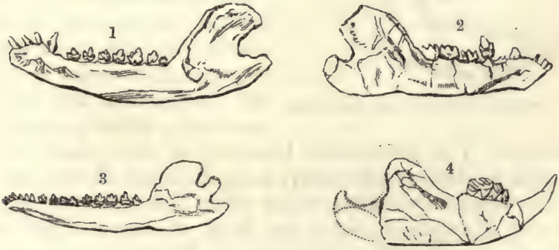

Fig. 370.—Oolitic Mammals, natural size. 1. Lower jaw and teeth of *Phascolotherium* 2. of *Triconodon;* 3. of *Amphitherium;* 4. of *Plagiaulax.*

In the Tertiary series of rocks Marsupials are of rare occurrence; but Opossums, closely allied to the existing American forms, have been discovered in the Miocene and Eocene rocks of Europe, and have been referred to a distinct genus under the name of *Peratherium*. It is also interesting to note that the Upper Jurassic beds have recently yielded to the researches of Professor Marsh the first fossil Marsupials which have been detected in the North American continent in beds older than the Post-pliocene, and that these belong to an extinct type of the at present exclusively American family of the *Didelphidæ*.

The next occurrence of Marsupials is in the later Tertiary (Pliocene) and in the Post-tertiary epoch; and here they are represented by some very remarkable forms. The remains in question have been found in the bone-caves of Australia—the country in which Marsupials now abound above every other part of the globe; and they show that Australia, at no distant geological period, possessed a Marsupial fauna, much resembling that which it has at present, but of forms comparatively of a much more gigantic size. In the remains from the Australian bone-caves almost all the most characteristic living Marsupials of Australia and Van Diemen's Land are represented; but the extinct forms are usually of much greater size. We have Wombats, Phalangers, Flying Phalangers, and Kangaroos, with carnivorous Marsupials resembling the recent *Thylacinus* and *Dasyurus*. The two most remarkable of these extinct forms are *Diprotodon* and *Thylacoleo*. In most essential respects *Diprotodon* resembled the Kangaroos, the dentition, especially, showing many points of affinity. The hind-limbs, however, of *Diprotodon* were by no means so disproportionately long as in the Kangaroos. In size *Diprotodon* must have many times exceeded the largest of the living Kangaroos, since the skull measures three feet in length (fig. 371). The affinities of *Thylacoleo* are disputed. The great feature in the dentition is the presence in either jaw of one huge, compressed, and trenchant præmolar. This is regarded as corresponding to the great cutting præmolar of the Kangaroo-rats (*Hypsiprymnus*). Upon the whole, therefore, Professor Flower concludes that "*Thylacoleo* is a highly modified and aberrant form of the type of Marsupials now represented by the *Macropodidæ* and *Phalangistidæ*, though not belonging to either of these families as now restricted," and

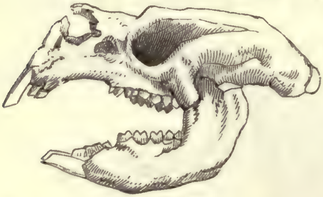

Fig. 371.—Skull of *Diprotodon australis*.

he believes that its diet was of a vegetable nature. On the other hand, Professor Owen is of opinion that *Thylacoleo* was probably carnivorous in its habits. This distinguished naturalist thus regards *Thylacoleo* as an ancient form of the Diprotodont Marsupials (Kangaroos, &c.), adapted for carnivorism, but not anatomically related to the true Carnivorous or Polyprotodont Marsupials (such as *Thylacinus* and *Dasyurus*). Under any view of its habits, *Thylacoleo* is a very remarkable type of the Marsupials; and it must have attained a very great size, since the length of the crown of the great præmolar is not less than two inches and a quarter.

PLACENTAL MAMMALS.

CHAPTER LXX.

EDENTATA.

ORDER III. EDENTATA or BRUTA.—The lowest order of the placental or monodelphous Mammals is that of the *Edentata*, often known by the name of *Bruta*. The name *Edentata* is certainly not an altogether appropriate one, since it is only in two genera in the order that there are absolutely no teeth. The remaining members of the order have teeth, but these are *always destitute of true enamel, are never displaced by a second set, and have no complete roots. Further, in none of the Edentata are there any median incisors, and in only one species (one of the Armadillos) are there any incisor teeth at all. Canine teeth, too, are almost invariably wanting. Clavicles are usually present, but are absent in the Scaly Ant-eater (Manis). All the toes are furnished with long and powerful claws.* The mammary glands are usually pectoral, but are sometimes abdominal in position. The testes are abdominal in position. *The skin is often covered with bony plates or horny scales.*

The placentation of the Edentates varies, the placenta being discoidal and deciduate in the Sloths (*e.g.*, *Cholœpus Hoffmanni*), but diffuse and non-deciduate in *Manis* (Turner)—a fact which throws some doubt on the propriety of using the placental characters in classification.

The order *Edentata* is conveniently divided into two great sections, in accordance with the nature of the food, the one section being phytophagous, the other insectivorous. In the former section is the single group of the Sloths (*Bradypodidæ*). In the latter are the two groups of the Armadillos (*Dasypodidæ*), and the various species of Ant-eaters (the latter constituting Owen's group of the *Edentula*).

The order *Edentata* is but sparingly represented in modern times, and its geographical distribution is peculiar. The true

Ant-eaters, the Armadillos, and the Sloths, are entirely confined to South America, in which country a group of gigantic extinct Edentates existed in Post-tertiary times. The Scaly Ant-eater or *Manis* is common to Asia and Africa, and the genus *Orycteropus* is peculiar to Africa.

The family *Bradypodidæ* (or *Tardigrada*) comprises some exceedingly curious animals, which are exclusively confined to South America, inhabiting the vast primeval forests of that continent. The Sloths have a remarkably short and rounded face, and the body is covered with hair. The mammæ are two in number and pectoral in position; and the tail is short or quite rudimentary. The incisor teeth are altogether wanting (fig. 372, A), but there is always a small number of simple molars, and in the Two-toed Sloths or Unaus the first tooth in each jaw on each side is so much larger than the others, and so much more pointed, that it has been regarded as a canine. The malar bone is not directly articulated with the temporal bone, and it sends backwards two long processes, directed respectively upwards and downwards (fig. 372, A). The stomach is complex, somewhat resembling that of the Ruminants. The cervical vertebræ are more than the normal seven in number in the Three-toed Sloth, and less than the normal in one of the two-toed species; and the long bones have no medullary cavities.

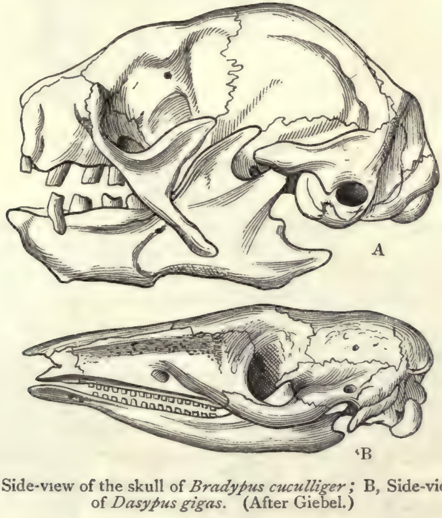

Fig. 372.—A, Side-view of the skull of *Bradypus cuculliger*; B, Side-view of the skull of *Dasypus gigas*. (After Giebel.)

The most striking peculiarities, however, about the Sloths are connected with their mode of life. The Sloths, in fact, are constructed to pass their life suspended from the under surface of the branches of the trees amongst which they live; and for this end their organisation is singularly adapted. The fore-limbs are much longer than the hind-limbs, and the bones of the fore-arm are unusually movable. All the feet, but especially the fore-feet, are furnished with enormously long curved claws (fig. 373), by the aid of which the animal is enabled to move about freely, suspended back downwards from the branches. Not only is this the ordinary mode of progression among the Sloths, but even in sleep the animal retains this apparently unnatural position.

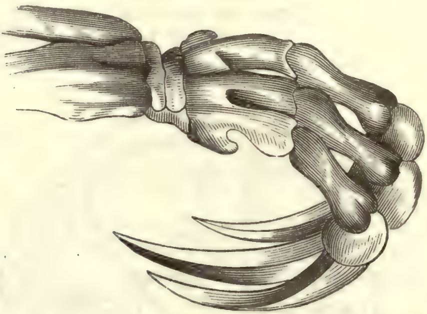

Fig. 373.—Hand of Three-toed Sloth (*Bradypus tridactylus*). (After Owen.)

Owing to the disproportionate size of the fore-limbs, as compared with the hind-limbs, and owing to the fact that the hind-feet are so curved as to render it impossible to apply the sole to the ground, the Sloth is an extremely awkward animal upon the ground, and it has therefore recourse to terrestrial progression only when absolutely compelled to do so. Whilst the name of "Sloth" may thus appear to be a merited one from the point of view of a terrestrial Mammal, it is wholly undeserved when the animal is looked upon as especially adapted for an arboreal existence. In the Ai or Three-toed Sloth (*Bradypus tridactylus*) there are three toes to each foot, and these are short, completely rigid, and so enveloped in the integument as to leave nothing visible except the enormously long and crooked claws. The hand and foot are jointed to the arm and leg obliquely, so that the palm and sole cannot be applied to the ground, but are turned inwards. The ungual phalanges are also so articulated that the claws are bent inwards towards the palm or sole. There are sixteen pairs of ribs. The molars are $\frac{5-5}{4-4}$, or $\frac{5-5}{5-5}$, rootless, growing from permanent pulps, and consisting of a simple cylinder of dentine enveloped in cement. In the Unau (*Cholœpus*) the fore-feet are two-toed, and there are twenty-three pairs of ribs, the greatest number known in the Mammals.

The second family of the *Edentata* is that of the *Dasypodidæ* or Armadillos. These are found exclusively in South America, as are the Sloths, but they are very different in their habits. The Armadillos are burrowing animals, furnished with strong digging-claws and well-developed collar-bones. They feed upon insects, worms, carrion, roots, and fruits. The jaws are provided with numerous simple molars (fig. 372, B), which attain the enormous number of nearly one hundred in the great Armadillo (*Priodontes gigas*). The upper surface of the body is covered with a coat of mail, formed of hard bony plates or shields united at their edges (fig. 374). A portion of this armour covers the head and shoulders, and another portion protects the hind-quarters; whilst between these is generally a variable number of movable bands which run transversely

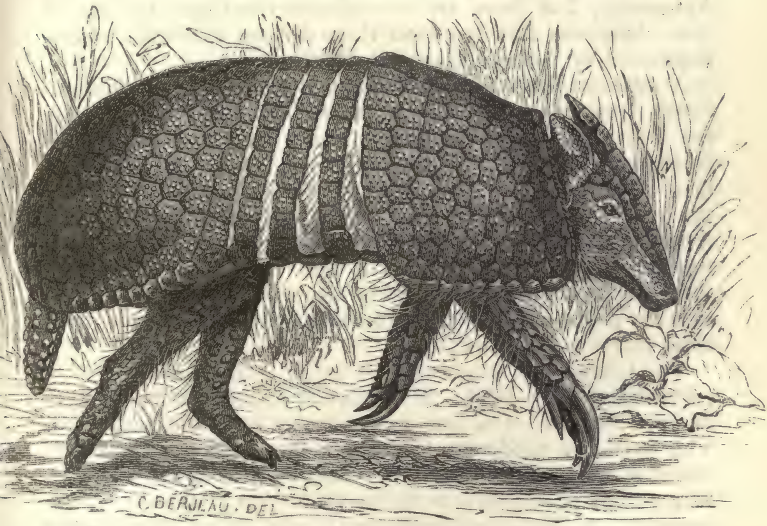

Fig. 374.—The three-banded Armadillo (*Tolypeutes conurus*), one-third of the natural size. (After Murie.)

across the body and give the necessary flexibility to this singular dermoskeleton. In most species this flexibility is so great that the animal can roll itself up like a hedgehog. The tail is likewise mostly covered with bony scutes. The spinous processes of the second cervical and of all the dorsal vertebræ are specially developed to carry the dermal shield. The sternum and first rib are expanded, and sternal ribs are present.

The Armadillos are confined entirely to America, ranging from Mexico to Patagonia. In this country, also, have been found the remains of the gigantic armour-plated animals allied to the Armadillos, which will be subsequently described under the name of *Glyptodon*. Amongst the best-known species of Armadillo are the Peba (*Dasypus Peba*), the Poyou (*D. sexcinctus*), the Tatouay (*D. Tatouay*), the Pichiy (*D. minutus*), the Peludo (*D. villosus*), and the Great Armadillo (*Priodontes gigas*). A somewhat aberrant form is the *Chlamyphorus*, or *Chlamydophorus*, of Chili, the total length of which is only about six inches.

The remaining members of the *Edentata* are the various Ant-eaters; but these are so different from one another in their characters that they form three distinct families, also distinguished by their geographical distribution.

a. Myrmecophagidæ.—This family is exclusively confined to South America, as are the two preceding, and it contains only the Hairy or true Ant-eaters. These curious animals feed chiefly upon Ants and Termites, which they catch with their long sticky tongues. The jaws are wholly destitute of teeth; the body is covered with hair; there is a long tail; and the feet are armed with long and strong, curved digging-claws. The toes are united by skin up to the bases of the claws, as in the Sloths; the ungual phalanges are articulated in the same way; and the palms of the hands are similarly turned inwards, their sides carrying a callous pad.

The best-known species of this family is the Great Ant-eater (*Myrmecophaga jubata*). This singular animal attains a length of over four feet, and has an extremely long and bushy tail. The jaws are produced to form a long and slender snout, which is entirely enclosed in the skin, till just at its extremity, where there is an aperture for the protrusion of the thread-like tongue. A bird-like character is the horny gizzard-like stomach. The anterior feet have four, and the posterior feet five toes, all armed with strong curved claws, which, in the case of the fore-feet, when not used in digging, are bent inwards, so that the animal walks on the sides of the feet; whereas the soles of the hind-feet touch the ground. The animal is perfectly harmless and gentle, when unmolested, and leads a solitary life. It lives mainly upon Termites, into the nests of which it forces its way by means of the powerful claws. When the Termites rush out to see what is the matter, the Ant-eater captures them by thrusting out its glutinous tongue, an action which can be repeated with marvellous rapidity.

In the closely-allied genus *Tamandua* the feet are four-toed, and the animal is arboreal in its habits, as is also the case with the *Cyclothurus*. In the latter the fore-feet are two-toed, and the hind-feet are four-toed, with a rudimentary hallux. In accordance with their mode of life these forms have prehensile tails, and in the last-mentioned genus well-developed clavicles are present.

b. Manidæ.—This family includes only the Scaly Ant-eaters or Pangolins, all exclusively confined to the Old World, and found in both Africa and Asia. The whole of the body, limbs, and tail in the *Manidæ* is covered with an armour of horny imbricated plates, overlapping like the tiles of a house, and apparently consisting of agglutinated hairs. The legs are short, and furnished with four or five toes each, ending in long and strong digging-claws; but there are no clavicles. The tongue resembles that of the Hairy Ant-eaters in being long and contractile, and capable of being exserted for a considerable distance beyond the mouth. It is covered with a glutinous saliva, and is the agent by which the animal catches ants and other insects. The jaws are wholly destitute of teeth. When threatened by danger, the Pangolins roll themselves up into a ball, like the hedgehogs. The tail is comparatively long, and is covered with scales. Though very strong for their size, only one of the species (*M. gigantea*, of Africa) attains a length of more than three or four feet, inclusive of the tail. The best-known species are the *Manis pentadactyla* of India, and the *Manis tetradactyla* of Africa. Other species occur in Java, Sumatra, and China.

c. Orycteropidæ.—The last family of the living Edentata is that of the *Orycteropidæ*, comprising only the single genus *Orycteropus*. This genus comprises two or three species, the best known being *O. capensis*, which is peculiar to South Africa, and is known by the Dutch colonists as the "Aardvark" or Ground-hog. The animal is nocturnal in its habits, and lives upon insects. The body is elongated, and the tail is long, the species attaining a total length of four feet or more. The zygomatic arch is complete. The legs are short, and the feet plantigrade, the anterior pair having four unguiculate toes, the posterior five. The claws are strong and curved, and enable the animal to construct extensive burrows. The skin is very thick, and is thinly covered with bristly hairs; and the tail is hairy. The head is elongated, and the mouth small—devoid of incisor and canine teeth (fig. 375), but furnished with a number of cylindrical molars $\left(\frac{7-7}{6-6}\right)$. The crowns of the molars are flat, and they are composed of dentine traversed by numerous dichotomising pulp-cavities, their cross-section resembling a piece of bamboo cut across. The tongue is long, flat, and slender, and is covered by a sticky saliva, by the aid of which the animal catches insects. The head is long and attenuated, the snout truncated and callous, and the ears large, erect, and pointed. Other species of *Orycteropus* occur in Senegal and Southern Nubia.

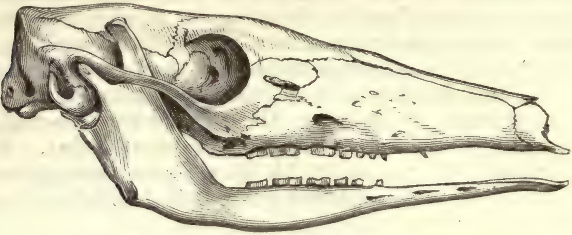

Fig. 375.—Skull of *Orycteropus capensis.*

As regards their *distribution* in *time*, the oldest Edentates at present known occur in Europe, in which country no members of the order now exist. These are the *Macrotherium* and *Ancylotherium* of the Miocene Tertiary, both apparently allied to the *Orycteropidæ*, with affinities to the *Manidæ*. The Pliocene deposits of North America have yielded to the researches of Professor Marsh two large *Edentates* of the new genus *Morotherium*, and the Miocene deposits of the same country contain remains of another Edentate type (*Moropus*). It is, however, in the Post-tertiary deposits of the American continent, and especially of South America—the present metropolis of the order—that we find the most abundant and the most remarkable remains of Edentate animals. Here, both in Post-pliocene superficial deposits and in cave-earths of the same age, we meet with the remains of numerous Edentates often of gigantic size, but in the main representing the existing types.

Thus the existing Sloths are represented in the Brazilian bone-caves by a number of extinct genera of *Bradypodidæ*, whilst the Post-pliocene sands and gravels of the open country have yielded the bones of various huge Edentates, resembling the Sloths in most essential respects, but adapted for a terrestrial instead of an arboreal life. Of these great "Ground-sloths" (*Gravigrada*), the most remarkable are the *Megatherium* (fig. 376), which attained a length of eighteen feet, with bones as massive as, or more so than, those of the Elephant; and the *Mylodon* and *Megalonyx*, both of which extended their range into the United States.

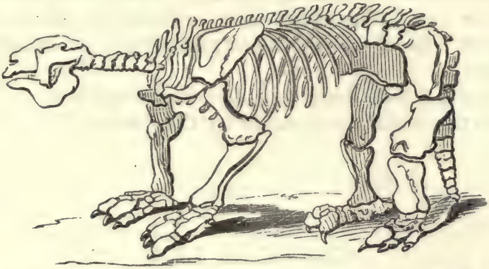

Fig. 376.—Skeleton of *Megatherium*. Post-tertiary, South America.

In the same way the little banded Armadillos of South America were formerly represented by gigantic species, constituting the genus *Glyptodon*. The *Glyptodons* (fig. 377) differed from the living Armadillos in having no bands in their armour, so that they must have been unable to roll themselves up. It is rare at the present day to meet with any Armadillo over two or three feet in length; but the length of the *Glyptodon clavipes*, from the tip of the snout to the end of the tail, was more than nine feet.

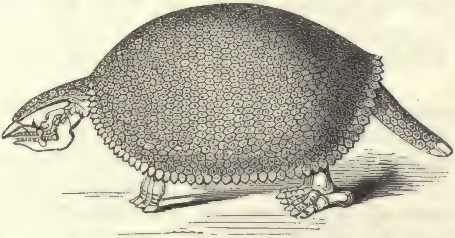

Fig. 377.—*Glyptodon clavipes*. Pleistocene deposits of South America.

The trunk-armour of *Glyptodon* is formed of nearly hexagonal bony scutes, forming a massive dome, for the support of which the skeleton is specially modified. Thus the last cervical and first two dorsal vertebræ are anchylosed to form a single bone ("trivertebral bone" of Huxley), which articulates by a movable hinge-joint with the remaining dorsal vertebræ, which are likewise anchylosed to form a kind of "tunnel or arched bridge of bone." The last two lumbar vertebræ are also fused with the sacral and caudal to form a continuous bony mass, whilst the ilia are of enormous size. Numerous extinct forms of genuine Armadillos have also been found in the Brazilian bone-caves, one of them (*Chlamydotherium*) being as big as a Rhinoceros.

Lastly, the South American *Myrmecophagidæ* are represented in the Brazilian cavern-deposits by the extinct *Glossotherium.*

CHAPTER LXXI.

SIRENIA AND CETACEA.

ORDER IV. SIRENIA.—This order comprises no other living animals except the Dugongs and Manatees, which have been often placed with the true *Cetaceans* (Whales and Dolphins) in a common order. There is no doubt, in fact, but that the *Sirenia* present certain alliances to the *Cetacea;* and though they are to be regarded as separate orders, yet, from one point of view, they may be considered as belonging to a single section, which has been called *Mutilata*, from the constant absence of the hind-limbs.

The *Sirenia* agree with the Whales and Dolphins in their complete adaptation to an aquatic mode of life (fig. 378); especially in *the presence of a powerful caudal fin, which differs from that of Fishes in being placed horizontally, and in being a mere expansion of the integuments, not supported by bony rays. The hind-limbs are wholly wanting;* and there is no sacrum. The anterior limbs* (fig. 379) *are converted into swimming-paddles or "flippers." The snout is fleshy and well-developed, and the nostrils are placed on its upper surface, and not on the top of the head, as in the Whales.* Fleshy lips are present, and the upper one usually carries a moustache. Ears are wanting. *The skin is covered with scattered bristles.* The head is not disproportionately large, as in the true Whales, and is not so gradually prolonged into the body as it is in the latter. There may be only six cervical vertebræ. The teats are two in number and are "thoracic," *i.e.*, are placed on the chest. There are no clavicles, and the digits have no more than three phalanges each. The testes are retained throughout life within the abdomen, but vesiculæ seminales are present. *The animal is diphyodont* (*Manatus*), *or monophyodont* (*Halicore*); *the permanent teeth consisting of molars with flattened crowns adapted for bruising vegetable food, and incisors which are present in the young animal, at any rate.* In the extinct *Rhytina* it does not appear that there were any incisor teeth; while in all the existing genera, the front of the upper and lower jaws is provided with rough horny pads or plates.

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* All the Sirenians possess a rudimentary pelvis, and in the extinct *Halitherium* a small femur is present in addition.

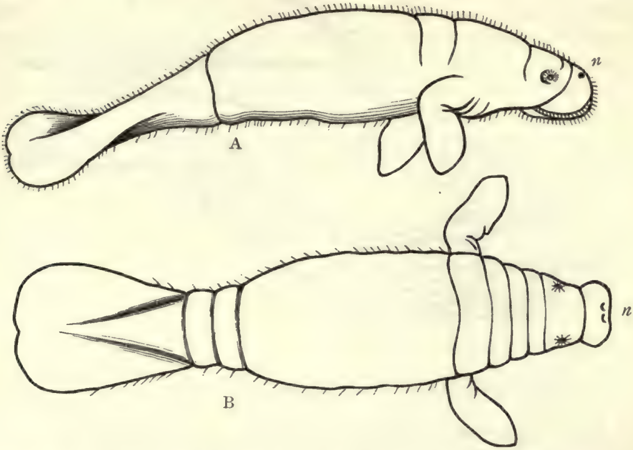

Fig. 378.—A, Side-view of young *Manatus Americanus;* B, The same viewed from above; *n* Nostrils. (After Murie.)

The only existing *Sirenia* are the Manatees (*Manatus*) and the Dugongs (*Halicore*), often spoken of collectively as "sea-cows," and forming the family of the *Manatidæ*.

The Manatees (fig. 380, B) are characterised by the possession of numerous $\frac{9-9}{9-9}$ to $\frac{11-11}{11-11}$ broad molars, which are never all in use at one time, while there are two small upper incisors, which do not cut the gum. The tail-fin is oblong or oval in shape, and the anterior limbs (fig. 379) are furnished with nails to the four outer digits. One species (*Manatus Americanus*) occurs on the east coast of North America, especially in the Gulf of Mexico, and another (*M. Senegalensis*) is found on the west coast of Africa. They are generally found in considerable numbers about the mouths of rivers and estuaries, often ranging far inland, and they appear to live entirely upon sea-weeds, aquatic plants, or the littoral vegetation. They are large, awkward animals, with a dense, rugose, hairy skin, attaining a length of from eight to ten feet as a rule, but sometimes growing to a length of nearly twenty feet.

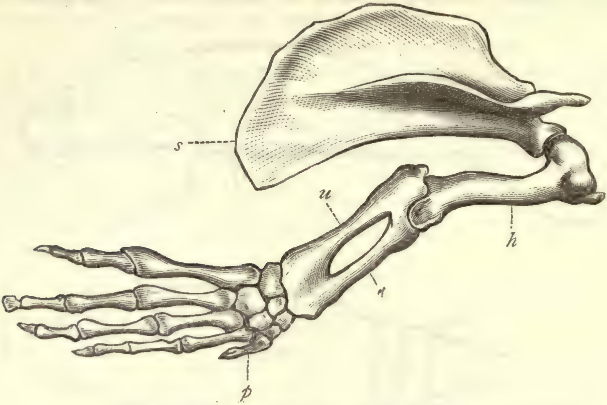

Fig. 379.—Fore-limb and hand of the Manatee (*Manatus Americanus*).

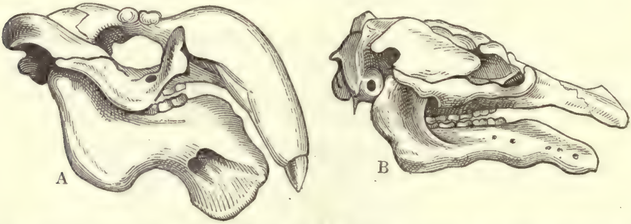

Fig. 380.—A, Side-view of the skull of the Dugong (*Halicore*), showing the tusk-like upper incisors; B, Side-view of the skull of Manatee (*Manatus*). (After Cuvier.)

The Dugongs (*Halicore*, fig. 380, A) have $\frac{5-5}{5-5}$ or $\frac{6-6}{6-6}$ molar teeth in the young condition, but these are never all in use at one time. The molars are without enamel, and are single-rooted. Inferior incisors are present in the young animal, but are wanting in the adult. The upper jaw carries two permanent incisors, which are entirely concealed in the jaw in the females, but which increase in size in the males with the age of the animal, till they become pointed tusks. Both upper and lower jaws are strongly bent down in front, and the deflexed portions of the jaws bear horny plates. The anterior extremities are nail-less, and the tail-fin is crescentic in shape. In their general appearance and in their habits the Dugongs differ little from the Manatees, and they are often killed and eaten. They attain a length of from eight to ten, twelve, or more feet, and are found on the coasts of the Indian Ocean and its islands, extending their range to the north coast of Australia. The bones are remarkable for their extreme density, their texture being nearly as close as ivory.

The Manatees and Dugongs, as before said, are the only living *Sirenia;* but besides these there is a very singular form, the *Rhytina Stelleri*, which is now extinct, having been exterminated by man within a comparatively recent period. This remarkable animal was discovered about the middle of the eighteenth century in a little island (Behring's Island) off the coast of Kamtchatka. Upon this island the celebrated voyager Behring was wrecked, and he found the place inhabited by these enormous animals, which were subsequently described by M. Steller, who formed one of his party. The discovery, however, was fatal to the *Rhytina*, for the last appears to have been seen in the year 1768. The *Rhytina* was an animal of great size, measuring twenty-five to thirty-five feet in length, and twenty feet at its greatest circumference. There can hardly be said to have been any true teeth, but the jaws contained $\frac{1-1}{1-1}$ large lamelliform fibrous structures, which officiated as teeth, and may be looked upon as molars. These singular structures are not *teeth*, in the true sense of this term; but they are similar to the horny tuberculated plates found in the front of the mouth of the Dugong and Manatee, and the upper ones may be regarded as the equivalent of the anterior palatine pad of the Ruminants (Murie). The epidermis was extremely thick and fibrous, and hairs appear to have been wanting. There was a crescentic tail-fin, and the anterior limbs alone were present.

As regards the *distribution* in *time* of the *Sirenia*, the oldest-known remains referable to the order are found in the Eocene Tertiary (*Eotherium*). Of the same age is probably the interesting form described from the Tertiary deposits of Jamaica by Owen under the name of *Prorastomus sirenoides.* This type is remarkable as possessing upper and lower canines in addition to molar and incisor teeth. The Miocene and Pliocene deposits of Europe have yielded remains of numerous Sirenians belonging to the genus *Halitherium*, in which there are tusk-like upper incisors (as in *Halicore*), combined with enamelled molars (as in *Manatus*), and in which a rudimentary femur is attached to the pelvis. Remains of *Rhytina* occur in the Post-pliocene of Siberia.

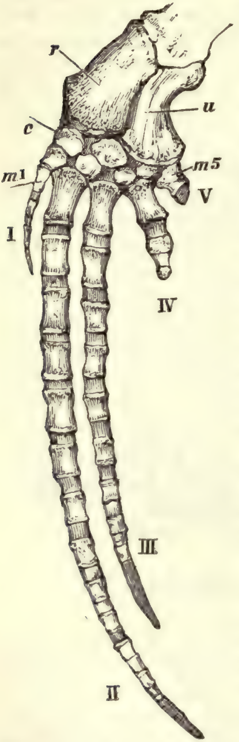

Fig. 381.—Hand of Round-headed Dolphin. I—V, Digits; *r* Radius; *u* Ulna; *c* Carpus; m^1, m^5 First and fifth metacarpal.

ORDER V. CETACEA.—In this order are the Whales, Dolphins, and Porpoises, all agreeing with the preceding in their complete adaptation to an aquatic life (figs. 384, 386). *The body is completely fish-like in form; the anterior limbs are converted into swimming-paddles or "flippers;" the proximal bones of the fore-limbs are much reduced in length, and the succeeding bones are shortened and flattened, and are enveloped in a tendinous skin, thus reducing the limbs to oar-like fins, the phalanges of some of the digits being sometimes increased in number* (fig. 381); *there are no external ears; the posterior limbs are completely absent; and there is a powerful, horizontally-flattened, caudal fin, sometimes accompanied by a dorsal fin as well.* In all these characters the *Cetacea* agree with the *Sirenia*, except in the one last mentioned. On the other hand, *the nostrils, which may be single or double, are always placed at the top of the head, constituting the so-called "blow-holes" or "spiracles;" and they are never situated at the end of a snout. The body of the adult is in general completely hairless.* The testes are retained throughout life within the abdomen, and there are no vesiculæ seminales. The teats are two in number, and are placed upon the groin. *The head is generally of disproportionately large size, and is never separated from the body by any distinct constriction or neck.* The lumbar region of the spine is long, and, as in the *Sirenia*, there is no sacrum, and the pelvis is represented by a single bone (the ischium) on each side. A rudimentary femur may be present, and *Balæna mysticetus* has a cartilaginous tibia as well. There are no clavicles, and the sternum is broad and flat in form. Lastly, *the adult is either destitute of teeth*, *or*, *with the single exception of the Zeuglodontidæ*, *is monophyodont*—that is to say, possesses but a single set of teeth, which are never replaced by others. *When teeth are present*, *they are usually conical and numerous*, *and*, *except in the Zeuglodonts*, *they are always of one kind only.*

The skull is often unsymmetrically developed, and the maxillæ and præmaxillæ are greatly prolonged. The nasal bones are short, and the nasal passages are vertically directed; the epiglottis and laryngeal cartilages being prolonged behind the soft palate in the form of a cylindrical tube, which is practically continuous with the posterior nares, thus allowing the animal to swallow under water without choking.

The *Cetacea* may be divided into the five families of the *Balænidæ* or Whalebone Whales, the *Delphinidæ* or Dolphins and Porpoises, the *Catodontidæ* or Sperm Whales, the *Rhynchoceti* or Ziphioid Whales, and the *Zeuglodontidæ*. Of these the *Balænidæ* are often spoken of as the "toothless" Whales, whilst the other four families are called the "toothed" Whales (*Odontoceti*).

Fam. 1. *Balænidæ.*—The *Balænidæ* or Toothless Whales are characterised by the total absence of teeth in the adult (fig. 382). Teeth are, however, present in the fœtal Whale, but they never cut the gum. The place of teeth is supplied by a number of plates of whalebone or "baleen" attached to the palate; hence the name of "whalebone whales" often given to this family. They are the largest of living animals, and may be divided into the two sections of the *Smooth* Whales, in which the skin is smooth and there is no dorsal fin (as in the Greenland Whale), and the *Furrowed* Whales, in which

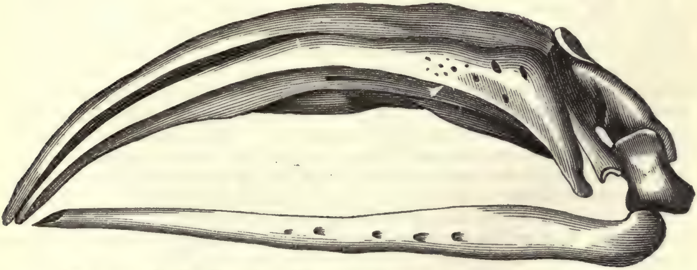

Fig. 382.—Skull of the Right Whale (*Balæna mysticetus*). (After Owen.)

the skin is furrowed and a dorsal fin is present (as in the so-called Finner Whales and Hump-backed Whales).

The Greenland or "Right" Whale (*Balæna mysticetus*) will illustrate almost all the leading points of interest in the family. The Greenland Whale is the animal which is sought after in the whale-fishery of Europe, and hence the name of "Right" Whale often applied to it. It is an inhabitant of the arctic seas, and reaches a length of from forty to sixty feet. Of this enormous length, nearly one-third is made up of the head, so that the eye looks as if it were placed nearly in the middle of the body. The skin is completely smooth, and is destitute of hairs in the adult. The fore-limbs are converted into "flippers" or swimming-paddles, but the main organ of progression is the tail, which often measures from twenty to twenty-five feet in breadth. The mouth is of enormous size, the upper jaw much narrower than the lower, and both completely destitute of teeth. Along the middle of the palate runs a strong keel, bordered by two lateral depressions, one on each side. Arranged transversely in these lateral depressions are an enormous number of horny plates, constituting what is known as the "baleen" plates, from which the whalebone of commerce is derived. The arrangement of the plates of baleen is as follows (fig. 383): Each plate is triangular in shape, the shortest side or base being deeply sunk in the palate. The outer edge of the plate is nearly straight, and is quite unbroken. The inner edge is slightly concave, and is furnished with a close fringe formed of detached fibres of whalebone. For simplicity's sake each baleen-plate has been regarded here as a single plate, but in reality each plate is composed of several pieces, of which the outermost is by far the largest, whilst the others gradually decrease in size towards the middle line of the palate. The large marginal plates are from eight to ten or more feet in length, and there may be over one hundred on each side of the mouth.

The object of the whole series of baleen-plates with which the palate is furnished, is as follows: The Whale is a strictly carnivorous or zoophagous animal, but owing to the absence of teeth and the comparatively small calibre of the œsophagus, it lives upon very diminutive animals. The Whale, in fact, lives mostly upon the shoals of small Pteropodous Molluscs, *Crustacea*, *Ctenophora* and *Medusæ*, which swarm in the arctic seas. To obtain these, the whale swims with the mouth opened, and thus fills the mouth with an enormous mass of water. The baleen-plates have the obvious function of a "screening apparatus." The water is strained through the numerous plates of baleen, and all the minute animals which it contains are arrested and collected together by the inner fibrous edges of the baleen-plates. When, by a repetition of this process, the Whale has accumulated a sufficient quantity of food within the central cavity of the mouth, it is enabled to swallow it, without taking the water at the same time.

We have now to speak of a phenomenon which has given rise to a considerable amount of controversy—namely, what is known as the "blowing" or "spouting" of the whale. In all the Cetaceans the nose opens by a single or double aperture (the latter in the *Balænidæ*) upon the top of the head, and these external apertures or nostrils are known as the "blow-holes" or "spiracles." The act known to the whalers as "blowing," consists in the expulsion from the blow-holes of a jet of what is apparently water, or at any rate looks like it. This act is performed by the whale upon rising to the surface, and it is usually by this that the whereabouts of the animal is discovered. The old view as to what takes place in the act of blowing is, that the whale is really occupied in getting rid of the surplus water which it has taken in at the mouth and strained through the baleen-plates. The modern and undoubtedly correct view, however, is, that the water which has been strained through the baleen really makes its escape at the sides of the mouth, and does not enter the pharynx to be expelled through the nose. Upon this view the apparent column of water emitted from the blow-holes in the act of blowing consists really of the expired air from the lungs, the contained watery vapour of which is suddenly condensed on its entrance into the cold atmosphere. With the expired air there may be such water as may have gained access to the nose through the blow-hole, for the expulsion of which proper provision exists in the form of muscular diverticula of the nasal cavity. It is also possible that the column of air in being forcibly expelled from the blow-hole may take up with it some of the superincumbent water.

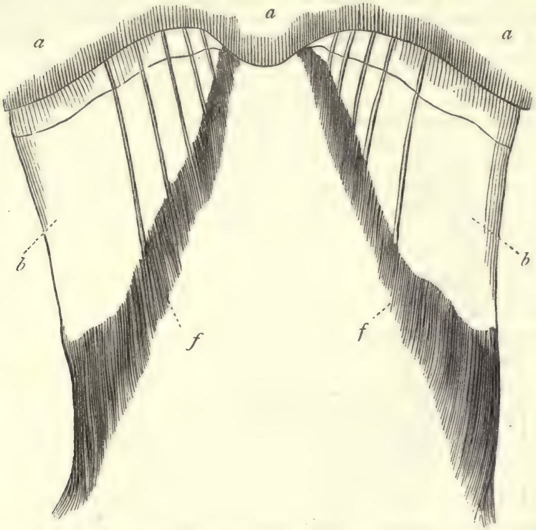

Fig. 383.—Diagram of the baleen-plates of a Whale. *a a* Section of the palatal surface of the upper jaw, showing the strong median ridge or keel; *b b* Baleen-plates sunk at their bases in the palate; *f f* Fibrous margin of baleen-plates.

The skin in the Right Whale is perfectly smooth and naked, but it is underlaid by a thick layer of subcutaneous fat, which varies from eight to fifteen inches in thickness, and is known as the "blubber." The blubber serves partly to give buoyancy to the body, but more especially to protect the animal against the extreme cold of the medium in which it lives. It is the blubber which is chiefly the object of the whale-fishery, as it yields the whale-oil of commerce.

The whale which is captured in the South Atlantic is not the same species as the Greenland Whale, and is termed the *Balæna australis.* It is much about the size of the Right Whale, averaging about fifty feet, but the head is proportionately smaller. Another Atlantic species is the *B. Biscayensis.* In the South Pacific occurs *Balæna antipodarum*, and in the

North Pacific we meet with the *B. Japonica* along with the *B. mysticetus* or Right Whale of the North Atlantic (Van Beneden).

The only remaining members of the *Balænidæ* which require notice are the Rorquals and Hump-backed Whales, constituting the group of the "Furrowed" Whales. These are collectively distinguished by having the skin furrowed or plaited to a greater or less extent, whilst the baleen-plates are short, and there is a dorsal fin. The specific determination of these animals is a matter of great difficulty, but there would appear to be probably three well-marked genera: 1. The genus *Megaptera*, including the so-called Hump-backed Whales, in which the flippers are of great length, from one-third to one-fifth of the entire length of the body. 2. The genus *Balænoptera*, comprising the so-called Rorquals or Piked Whales, in which the flippers are of moderate size. 3. The Finner Whales proper (*Physalus*).

In all these genera there is a dorsal adipose fin, so that they are all "Finner Whales." The *Balænopteræ* reach a gigantic size, being sometimes as much as eighty or one hundred feet in length. They are very active animals, however, and their whalebone is comparatively valueless, so that the whalers rarely meddle with them, though they are not uncommon, and are often driven ashore on our own coasts.

Fam. 2. *Catodontidæ.*—The family of the *Catodontidæ* or *Physeteridæ* comprises the Sperm Whales or Cachalots, with which we commence the series of the toothed Whales (*Odontoceti*). They are characterised by the fact that the palate is destitute of baleen-plates, and the lower jaw possesses a series (about fifty-four) of pointed conical teeth, separated by intervals, and sunk in a common alveolar groove, which is only imperfectly divided by septa. The upper jaw is also in reality furnished with teeth, but these do not cut the gum.

The best-known species of this family is the great Cachalot or Spermaceti Whale (*Physeter macrocephalus*, fig. 384). This animal is of enormous size, averaging from fifty to seventy feet in length, but the females

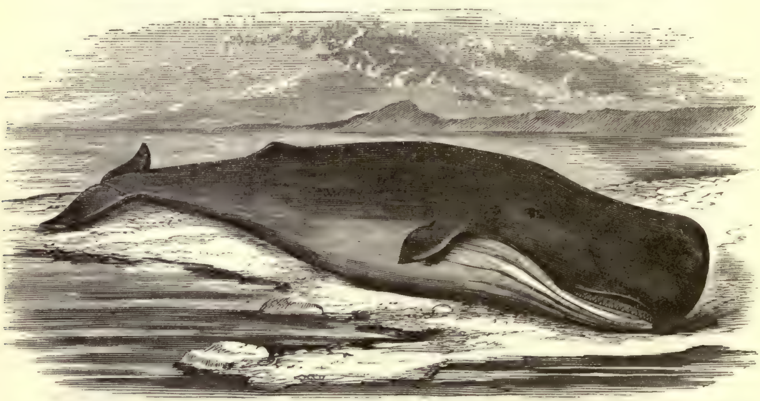

Fig. 384.—Spermaceti Whale (*Physeter macrocephalus*).

are a good deal smaller than the males. The head is disproportionately large, as in the *Balænidæ*, forming more than one-third of the entire length of the body. The snout forms a broad truncated muzzle, and the nostrils are placed near the front margin of this. The Sperm Whales live together in troops or "schools," and they are found in various seas, especially within the tropics. They are largely sought after, chiefly for the substance known as "spermaceti;" but besides this they yield oil and the singular body called "ambergris." The spermaceti is a fatty substance, which has the power of concreting when exposed to the air, being in life a clear white oily liquid. It is not only diffused through the entire blubber, but is also contained in special cavities of the head. The sperm-oil yielded by the blubber is exceedingly pure, and is free from the unpleasant odour of ordinary whale-oil. The ambergris is a peculiar substance which is found in masses in the intestine, and is probably of the nature of a biliary calculus, since it is said to be composed of a substance very nearly allied to cholesterine. It is used both as a perfume itself, and to mix with other perfumes.

Fam. 3. *Delphinidæ.*—This family includes the Dolphins, Porpoises, and Narwhal, and is characterised by usually possessing teeth in both jaws: the teeth being numerous, and conical in shape (fig. 385). The nostrils, as in the last family, are united, but they are placed further back, upon the top of the head. The single blow-hole or nostril is transverse and mostly crescentic or lunate in shape. The head is by no means so disproportionately large as in the former families, usually forming about one-seventh of the entire length of the body.

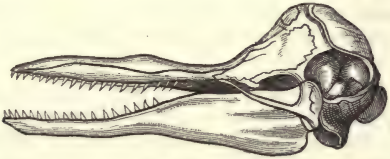

Fig. 385.—Side-view of the skull of *Delphinus tursio.* (After Cuvier.)

The most noticeable members of this family are the true Dolphins, the Porpoises, and the Narwhal.

The Dolphins have an elongated snout, separated from the head by a transverse depression. The common Dolphin (*Delphinus delphis*, fig. 386) is the best-known species. It averages from six to eight feet in length, and has the habit of swimming in flocks, often accompanying ships for many miles. The female, like most of the *Cetacea*, is uniparous. The Dolphin occurs commonly in all European seas, and is especially abundant in the Mediterranean.

The common Porpoise (*Phocæna communis*) is the commonest and smallest of all the *Cetacea*, rarely exceeding four feet in length. The head is blunt, and is not produced into a projecting muzzle. The Porpoise frequents the Atlantic, Pacific, Mediterranean, and Arctic Oceans, and the North Sea, and is commonly seen off our coasts. Another British species is the Grampus (*Orca gladiator*), but this is much larger, attaining a length of from eighteen to twenty feet. Nearly allied to the Grampus is the so-called "Caing" Whale, or, as it is sometimes termed, the Bottle-nosed Whale (*Globicephalus melas* or *Phocæna globiceps*). This species occurs not uncommonly round the Orkney and Shetland Islands, and attains a length of as much as twenty-four feet. It is gregarious in its habits, and is often killed for the sake of its oil.

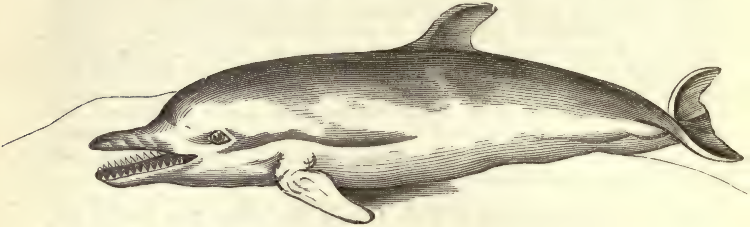

Fig. 386.—The common Dolphin (*Delphinus delphis*).

Closely allied to the true Dolphins are some curious Cetaceans, belonging to three genera, but all inhabiting fresh waters. One of these is the Gangetic Dolphin (*Platanista Gangetica*), which inhabits the Ganges, especially near its mouth. This singular animal is characterised by the great length of its slender muzzle, and by the small size of the eyes. It attains the length of seven feet, and the blow-hole is a longitudinal fissure, and therefore quite unlike that of the typical *Delphinidæ*. Closely allied to this, or identical with it, is the *Platanista Indi* of the Indus; while the *Orcella fluminalis* inhabits the Irawaddy. Another fresh-water form is the *Inia Boliviensis*, which inhabits the rivers of Bolivia, and is found at a distance of more than two thousand miles from the sea. Lastly, the *Pontoporia Blainvillii* is a small Dolphin which inhabits the rivers of the Argentine Republic and of Patagonia.

The last of the *Delphinidæ* is the extraordinary Narwhal or Sea-unicorn (*Monodon monoceros*). The Narwhal is an inhabitant of the arctic seas, and attains a length of as much as fifteen feet, counting in the body alone. The dentition, however, is what constitutes the great peculiarity of the Narwhal. The lower jaw is altogether destitute of teeth, and the upper jaw in the females also exhibits no teeth externally, as a general rule at any rate, though there are two rudimentary canines (often looked upon as incisors) which do not cut the gum. In the males, the lower jaw is likewise edentulous, but the upper jaw is furnished with two molar teeth concealed in the gum, and with two canines. Of these two upper canines, that of the right side is generally rudimentary, and is concealed from view. The left upper canine, on the other hand, is developed from a permanent pulp, and grows to an enormous size, continuing to increase in length throughout the life of the animal. It forms a tusk of from eight to ten feet in length, and it has its entire surface spirally twisted. As an abnormality, both the upper canines may be developed in this way so as to form projecting tusks; and it is stated that the tusk is occasionally present in the female. The function of this extraordinary tooth is doubtless offensive.

Fam. 4. *Rhynchoceti.*—This family is allied to the Cachalots or Sperm Whales, and includes the so-called "Ziphioid Whales." They are distinguished by the possession of a pointed snout (the "beak" or "rostrum"), single blow-hole, small dorsal fin, and dentition. The upper jaw is greatly extended and is edentulous, any teeth which may be present not cutting the gum. The lower jaw, on the other hand, possesses usually a single pair of teeth, sometimes two pairs, which are sometimes tusk-like, but which in other cases are concealed by the gum, and are always most conspicuous in the males.

The rostrum of these Cetaceans is of great density, and has often been preserved in a fossil state, usually presenting itself as a bony cylinder or elongated cone, generally more or less water-worn. The most important living genera are *Hyperoodon* and *Ziphius*, of which the former is found in the North Atlantic, and the latter in the Mediterranean and South Atlantic. The genera *Berardius* and *Mesoplodon* belong to the New Zealand province, species of the latter having been obtained at the Cape of Good Hope and on the coasts of Britain and France.

Fam. 5. *Zeuglodontidæ.*—The members of this family differ from all existing *Odontoceti* in the possession of molar teeth implanted by two distinct fangs. Incisor teeth are likewise present, and the animal is diphyodont. The Zeuglodonts are entirely extinct, and they are exclusively confined to the Eocene, Miocene, and Pliocene periods. The chief genera are *Zeuglodon* and *Squalodon*.

Zeuglodon (fig. 387) is distinguished by its elongated snout, conical incisors, and molar teeth with triangular serrated crowns, implanted in the jaw by two roots. Each molar looks

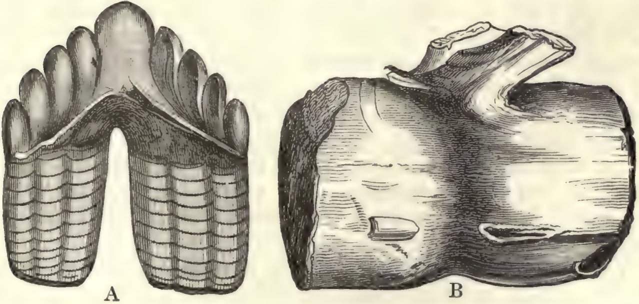

Fig. 387.—*Zeuglodon cetoides.* A, Molar tooth, natural size; B, Vertebra, reduced. From the Middle Eocene of North America. (After Lyell.)

as if it were composed of two separate teeth united on one side by their crowns; and it is this peculiarity which is expressed by the generic name. The species of *Zeuglodon* are Eocene and Miocene. The species of *Squalodon* are Miocene and Pliocene.

As regards the distribution of the *Cetacea* in *time*, no member of the order has yet been detected in any Secondary deposit. The Zeuglodonts, as just remarked, extend from the Eocene to the Pliocene, *Zeuglodon* itself being the oldest Cetacean at present known. The Ziphioid Whales begin in the Pliocene, as do the *Catodontidæ;* but the *Delphinidæ* are known to occur in the Miocene. The *Balænidæ* are not known to have existed earlier than the Pliocene.

CHAPTER LXXII.

UNGULATA.

ORDER VI. UNGULATA.—The order of the *Ungulata*, or Hoofed Quadrupeds, is one of the largest and most important of all the divisions of the *Mammalia*. It comprises three entire old orders—namely, the *Pachydermata*, *Solidungula*, and *Ruminantia*.

The first of these old divisions—that of the *Pachydermata*—included the Elephants, Rhinoceros, Hippopotamus, Tapirs, and the Pigs, all characterised, as the name implies, by their thick integuments. The name is still used to express this fact, though the order is now abandoned, and is merged with that of the *Ungulata;* the Elephants alone being removed to a separate order under the name of *Proboscidea*.

The second old order—that of the *Solidungula* or Solipedes—included the Horse, Zebra, and Ass, all characterised by the fact that the foot terminates in a single toe, encased in an expanded hoof. The name *Solidungula* is still retained for these animals, as a section of the *Ungulata*.

The third old order—that of the *Ruminantia*—includes all those animals, such as Oxen, Sheep, Goats, Camels, Giraffes, Deer, and others, which chew the cud or "ruminate," and have two functional toes to each foot, encased in hoofs. The name *Ruminantia* is still retained for these animals, as constituting a most natural group of the *Ungulata*.

All these various animals, then, are now grouped together into the single order of the *Ungulata*, or Hoofed Quadrupeds, and the following are the characters of the order :—

All the four limbs are present, and that portion of the toe which touches the ground is always encased in a greatly-expanded nail, constituting a "hoof." Only in a few extinct forms (the Coryphodontidæ) are there more than four full-sized toes to each limb. Owing to the encasement of the toes in hoofs, the limbs are useless for prehension, and only subserve locomotion; hence clavicles are always wanting in the entire order. There are always two sets of enamelled teeth, so that the animal is diphyodont. The molar teeth are massive and have broad crowns, adapted for grinding vegetable substances.

In accordance with the number of the digits (fig. 388), the order *Ungulata* is divided into two primary sections: The *Perissodactyla*, in which the toes or hoofs are odd in number (one or three, or, in the extinct *Coryphodontidæ*, five), and the *Artiodactyla*, in which the toes are even in number (two or four).

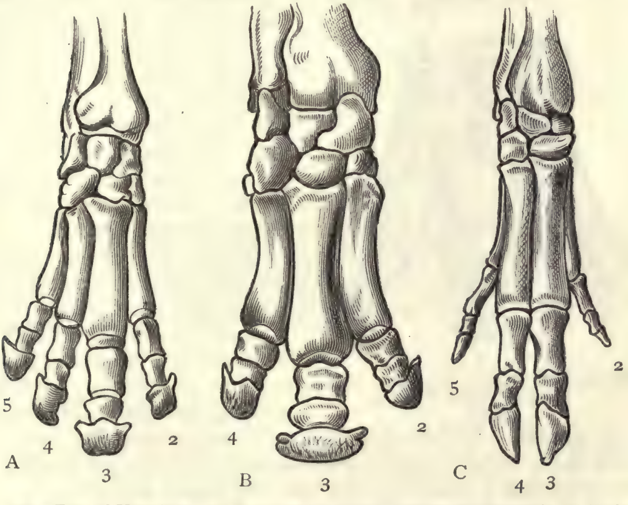

Fig. 388.—Feet of Ungulata. A, Fore-foot of Tapir (*Tapirus Malayanus*); B, Perissodactyle fore-foot of *Rhinoceros Sumatrensis*; C, Artiodactyle foot of Pig (*Sus scrofa*). The figures indicate which of the normal five digits are present in each foot. (After Flower.)

PERISSODACTYLE UNGULATES.

SECTION A. PERISSODACTYLA.—The section of the *Perissodactyle* Ungulates includes the Rhinoceros, the Tapirs, the

Horse and its allies, and some extinct forms, all agreeing in the following characters:—

The hind-feet are odd-toed in all (fig. 388, B), *and the fore-feet in all except the Tapirs and Brontotheridæ. The dorso-lumbar vertebræ are never less than twenty-two in number. The femur has a third trochanter. The horns, if present, are not paired* (*except in the extinct genus Diceratherium, and in the family of the Brontotheridæ*). *Usually there is only one horn, but if there are two, these are placed in the middle line of the head, one behind the other* (fig. 392). *In neither case are the horns ever supported by bony horn-cores. The stomach is simple, and is not divided into several compartments; and there is a large and capacious cæcum.*

The three existing groups of Perissodactyle Ungulates—namely, the Horses, Tapirs, and Rhinoceroses—are widely removed from one another in many important characters; but the intervals between them are largely filled up by an extensive series of fossil forms, commencing in the Lower Tertiary strata.

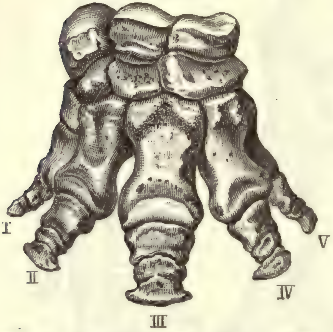

Fig. 389.—Fore-foot of *Coryphodon*. (After Marsh.) Eocene Tertiary.

The section of the Perissodactyle Ungulates includes the following seven families:—

Fam. 1. *Coryphodontidæ.*—This family comprises only a number of extinct Tapir-like animals, belonging to the Eocene period. The skull is of the Perissodactyle type, hornless, with small nasal bones. The brain is remarkably small, and the dentition is complete, the dental formula being—

$$i\,\frac{3-3}{3-3};\ \ c\,\frac{1-1}{1-1};\ \ pm\,\frac{4-4}{4-4};\ \ m\,\frac{3-3}{3-3} = 44.$$

The canines are not excessively developed, and the molars are of the Tapiroid type, having two transverse crests or ridges. The limbs are short, and both the fore-feet (fig. 389) and the hind-feet are furnished with five complete toes, all of which carried hoofs. The genus *Coryphodon* is the principal or only one comprised in the family; and as it contains the only Ungulates with the complete number of five digits on each foot, it might with propriety be raised to the rank of a distinct section, equal with the sections of the *Perissodactyla* and

Artiodactyla, to which the name of *Teleodactyla* might be applied.

Fam. 2. *Rhinocerotidæ.*—This family comprises only a single living genus, the genus *Rhinoceros*, unless, indeed, the little *Hyrax* is to be retained in this order. The Rhinoceroses are extremely large and bulky brutes, having a very thick skin, which is usually thrown into deep folds. The muzzle is rounded and blunt, and there are $\frac{7-7}{7-7}$ grinders, with tuberculate crowns. The typical dental formula is—

$$i\,\frac{1-1}{1-1}\left(\text{or }\frac{0-0}{0-0}\right);\quad c\,\frac{0-0}{0-0};\quad pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3}=32\text{ or }28.$$

There are no canines; and the incisors are often wanting in the adult (as in the living two-horned species), or may be increased in number (as in the extinct *Acerotherium*). The crowns of the præmolars and molars (fig. 390) exhibit two principal tracts of dentine, not filled up by cement.

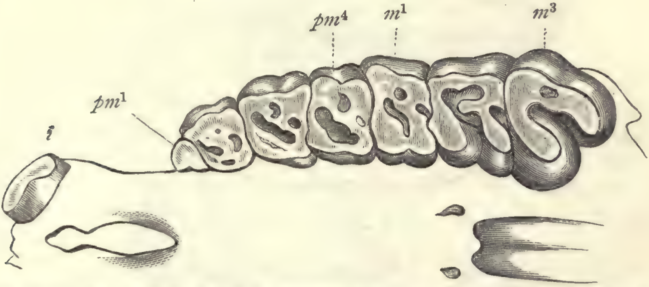

Fig. 390.—Teeth of the upper jaw of *Rhinoceros Indicus* (after Cuvier). m^1, m^3 Molars; pm^1, pm^4 Præmolars; *i* Incisor.

The skull (fig. 391, B) is pyramidal, and the nasal bones are generally enormously developed. The nasal bones usually support one or two horns, which are not paired in any living form. The horn is composed of longitudinal fibres, which are agglutinated together, and are of the nature of epidermic growths, somewhat analogous to hairs. When two horns are present, the hinder one is carried by the frontal bones, and is placed in the middle line of the head behind the anterior horn. The posterior horn is usually much shorter than the anterior one; and if not, it differs in shape. In the extinct genus *Diceratherium* of Marsh, from the Miocene of Oregon, there are two horns placed transversely and symmetrically upon the nasal bones. This singular form further differs from the typical Rhinoceroses in having four toes to the fore-feet, whilst the hind-feet have only three.

The development of the nasal bones in the Rhinoceroses varies greatly in accordance with the varying condition of the horns. In the extinct *Acerotherium,* in which there are no horns, the nasal bones are greatly reduced in size. In the horned forms, on the other hand, not only are the nasal bones prolonged forwards over the nasal cavity; but the septum narium may be partially or completely ossified, thus strengthening the basement of the anterior horn in the bicorn species.

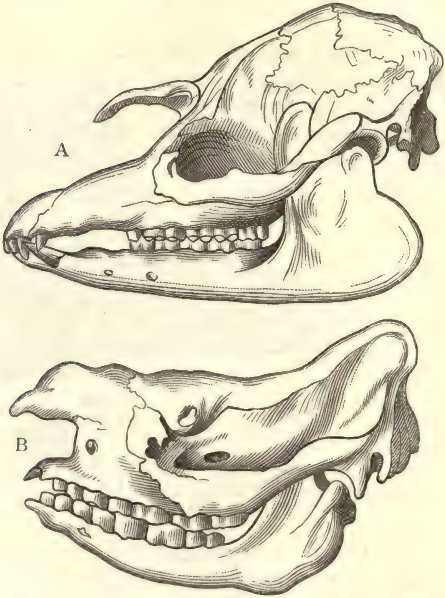

Fig. 391.—A, Side-view of the skull of *Tapirus Americanus;* B, Side-view of the skull of *Rhinoceros bicornis.* (After Giebel.)

The Rhinoceroses live in marshy places, and subsist chiefly on the foliage of trees. They are exclusively confined at the present day to the warmer parts of the Old World; but several extinct species formerly ranged over the greater part of Europe. Of the one-horned species, of which there are three, the best known is the Indian Rhinoceros (*R. Indicus* or *unicornis*), which was probably the "Unicorn" of the ancients. Another species with one horn (*R. Sondaicus*) inhabits the Malay Peninsula, Java, Sumatra, and Borneo. Of the two-horned species, one (*R. Sumatrensis*) is found in Sumatra and the Malay Peninsula, and is remarkable for the comparative absence of cutaneous folds. The best known, however, is the African Rhinoceros (*R. bicornis*) which occurs abundantly in Cape Colony and in the southern parts of the African continent, extending its range to Nubia (fig. 392). Another African species is the White Rhinoceros (*R. simus*), distinguished from the preceding by its colour, the shortness of its upper lip, and the great length of the anterior horn; and at least two other two-horned species are said to occur in the same country.

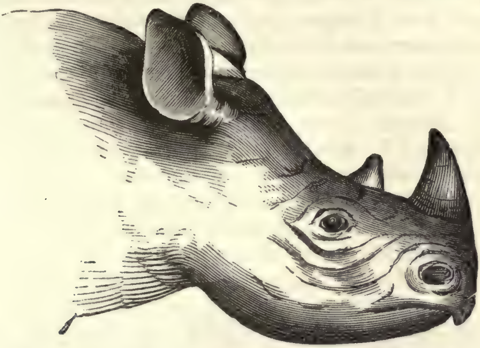

Fig. 392.—Head of two-horned Rhinoceros (*R. bicornis*).

Fam. 3. *Tapiridæ.*—The Tapirs are characterised by the possession of a short movable proboscis or trunk. The skull (fig. 391, A) is pyramidal, like that of the pigs, and the nasal bones project over the nasal cavity. The skin is hairy and very thick. The tail is extremely short. The fore-feet (fig. 388, A) have *four* toes each, but these are unsymmetrical (the little toe being smaller than the rest and not touching the ground), and the hind-feet have only three toes, all encased in hoofs. The dental formula of the Tapirs is—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{3-3};\quad m\,\frac{3-3}{3-3} = 42.$$

The canines are of comparatively small size, and do not form projecting tusks; and the molars and præmolars are of the "bilophodont" type, the crown of each showing two transverse or oblique ridges separated by shallow valleys.

Several species of Tapirs are known, of which the most familiar is the American Tapir (*T. Americanus*), which inhabits the vast forests of South America. It is a large animal, something like a pig in shape, but brownish black in colour, and having a mane. It is nocturnal in its habits, and is strictly phytophagous. The proboscis is employed in conveying the food to the mouth, and the nostrils are placed at its extremity. It attains altogether a total length of from five to six feet. Another species, with longer hair (*T. villosus*), inhabits the Andes, and a still larger species (*T. Malayanus*) is found in Sumatra, Borneo, and Malacca. In this last, there is no mane, and the general colour is black; but the back, rump, and sides of the belly are white. The *Elasmognathus Bairdii* occurs in Central America, and one or more species of the genus *Tapirus* (*T. Roulini* and *T. leucogenys*) have been discovered in the elevated regions of Ecuador and New Granada.

Fam. 4. *Brontotheridæ.*—We may provisionally place here the large fossil Mammals from the Miocene of North America, which Professor Marsh has described under the name of *Brontotheridæ.* In these, the fore-feet have four nearly equal toes, and the hind-feet three, thus resembling the Tapirs. The skull is elongated, and a pair of very large horn-cores are carried upon the maxillaries and the anchylosed nasal bones in both sexes. The dental formula in *Brontotherium* is—

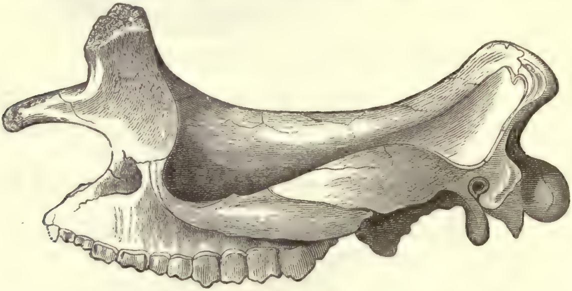

Fig. 393.—Skull of *Brontotherium ingens.* (After Marsh.)

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{3-3};\ m\,\frac{3-3}{3-3}=38.$$

The incisors are small; and the canines are short and not separated from the præmolars by any diastema, these latter being much smaller than the molars. The neck was long, and there seems to have been a long tail. The nose was probably elongated and flexible, but there would not appear to have been a long proboscis. The *Brontotheridæ* seem to be the successors of the *Dinocerata* of the Eocene. The chief genus is *Brontotherium*, with which the *Symborodon* and *Miobasileus* of Professor Cope are more or less entirely synonymous.

The genera *Titanotherium*, *Megacerops*, and *Diconodon*, also belong to this group.

Fam. 5. *Palæotheridæ*.—This family includes certain extinct Ungulates from the Eocene and Miocene Tertiary. They are characterised by the possession of three toes to all the feet, by having canines, and by the fact that the lower molars have a doubly crescentic form. The canines are longer than the other teeth, and the dental formula is—

$$i\,\frac{3-3}{3-3};\ c\ \frac{1-1}{1-1};\ pm\ \frac{4-4}{4-4};\ m\ \frac{3-3}{3-3} = 44.$$

The chief genus in this family is *Palæotherium* itself. Several species of this genus are known, varying in size from a sheep up to a horse. From the form and size of the nasal bones it is deduced, with great probability, that the *Palæotheridæ* possessed a short movable proboscis or trunk.

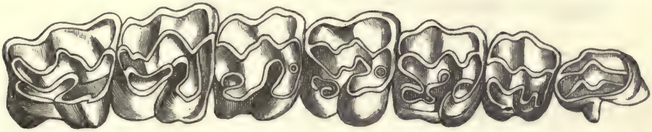

Fig. 394.—Grinding-surface of the molar and præmolar teeth of the upper jaw of *Palæotherium crassum*. (After Owen.)

Fam. 6. *Macrauchenidæ*.—This family comprises the single genus *Macrauchenia* from the late Tertiary deposits of South America. The animals included in this genus were of large size, with three-toed feet, and a third trochanter to the femur, but having cervical vertebræ of the type of those of the *Camelidæ*. The general form of the skull is horse-like, and the incisors have a coronal pit. The teeth form nearly a continuous series, and the dental formula is—

$$i\,\frac{3-3}{3-3};\ c\ \frac{1-1}{1-1};\ pm\ \frac{5-5}{4-4};\ m\ \frac{3-3}{3-3} = 46.$$

Fam. 7. *Solidungula* or *Equidæ*.—This family comprises the Horses, Asses, and Zebras, characterised by the fact that the feet, in living forms, have only a single perfect toe each, enclosed in a single broad hoof, without supplementary hoofs (figs. 355 and 397, D). The functional toe is the 3d, and the 2d and 4th digits are represented only by rudiments of their metapodials ("splint-bones"), hidden beneath the skin. There is a discontinuous series of teeth (fig. 395) in each jaw; and in the males, canines are present, but these are wanting in the females. The dental formula is—

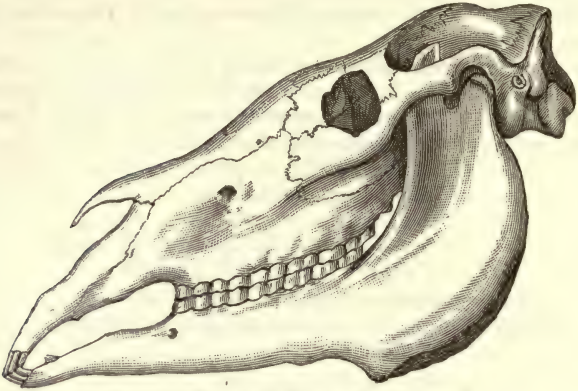

Fig. 395.—Skull of the Horse (*Equus caballus*).

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1}\left(\text{or }\frac{0-0}{0-0}\right);\ pm\,\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3}=40\text{ or }38.$$

The skin is covered with hair, and the neck is furnished with a mane.

As regards the dentition of the recent *Equidæ*, there are sometimes $\frac{4-4}{4-4}$ præmolars, but the first præmolar usually disappears in adult life. The canines are of small size. The outer side of the molars (fig. 396) is deeply grooved, with two parallel sulci, to which internal ridges correspond, their length being very great, and the whole external surface being thickly coated with cement; while the enamel-ridges and folds of the crown are filled in with the same substance. The enamel covering the incisors is folded in at the crown, like the inverted finger of a glove, the tube thus formed being filled in with soft cement; and it is the wearing down of this with age which constitutes the "mark."

The family *Equidæ* is divided by Dr Gray into two sections or genera: *Equus*, comprising the Horse; and *Asinus* comprising the Asses and Zebras. Many authorities, however, place all the existing forms under the single genus *Equus*.

The genus *Equus* is distinguished by the fact that the animal is not banded, and has no dorsal line; both the fore and hind legs have warts, and the tail is hairy throughout. The genus appears to contain no more than one well-marked species, if the Asses be excluded, and as far as living forms are concerned—namely, the *Equus caballus*. From this single species appear to have descended all the innumerable varieties of horses which are employed by man. The native country of the horse appears to have been Central Asia, but all the known wild individuals of the present day appear to be descendants of domestic breeds.

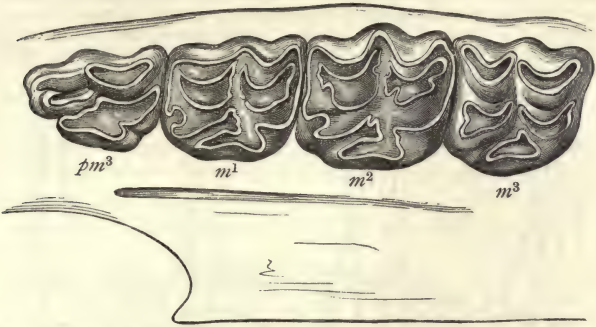

Fig. 396.—Grinding-surfaces of the last præmolar and of the three true molars of the upper jaw of the Horse. (After Cuvier.)

The Ass (*Asinus vulgaris*) is characterised by the fact that there is always a distinct dorsal line, and the body is more or less banded; the fore-legs alone have warts, and the tail has a tuft of long hair at its extremity. The Ass is probably a native either of Northern Africa, or of South-western Asia, and it has been supposed to be the descendant either of the "Djiggetai" (*Asinus hemionus*), or the "Onager" (*Asinus onager*), both wild existing species; though a more probable stock for it is to be found in the *Asinus tæniopus* of Abyssinia. According to Lenormant, the Ass was domesticated in Egypt at the very earliest periods of its history, long before the introduction of the Horse; and it may therefore be the descendant of a wild African form. The striped and banded asses are known as Zebras and Quaggas, and are distributed over the greater part of Africa. Several genera (*Anchitherium*, *Hipparion*, *Orohippus*, *Miohippus*, *Pliohippus*, &c.) have been founded upon the remains of fossil *Equidæ*. Many of these are of special interest, as showing an almost perfect series of gradations between a foot with three complete toes and a foot with only one complete digit. Some of them also exhibit other curious transitional characters.

The most ancient type of the *Equidæ* is the *Eohippus* of the Lower Eocene of North America, in which the fore-feet have four complete toes and a rudimentary pollex, while the hind-feet have three toes.

Orohippus is the next oldest known Equine genus, and comprises small mammals about as big as foxes, with the fore-feet four-toed (fig. 397, A), and the hind-feet three-toed. In the fore-foot, the pollex alone is wanting, but the middle toe is much the largest. The genus is from the Eocene of North America.

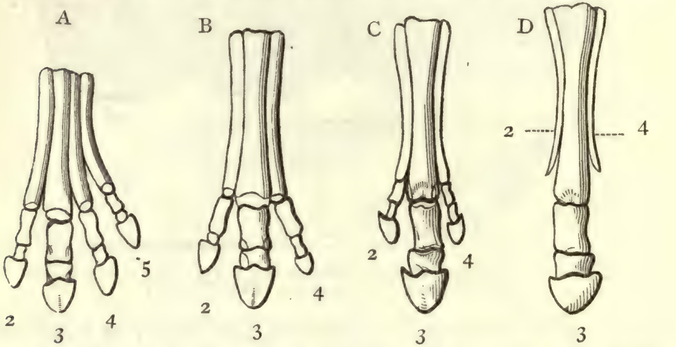

Fig. 397.—Skeleton of the foot in various forms belonging to the family of the *Equidæ:* A, Foot of *Orohippus*, Eocene; B, Foot of *Anchitherium*, Upper Eocene and Lower Miocene; C, Foot of *Hipparion*, Upper Miocene and Pliocene; D, Foot of Horse (*Equus*), Pliocene and Recent. The numerals indicate the numbers of the digits in the typical five-fingered hand of Mammals. (After Marsh.)

In the Miocene Tertiary occur the genera *Anchitherium*, *Miohippus*, and *Mesohippus*, all of which have three toes to both feet. *Mesohippus* has an additional "splint-bone" (rudimentary metacarpal, or metatarsal) representing a fourth toe. *Miohippus*, about as big as a sheep, has the three toes sub-equal, and all touching the ground. *Anchitherium* (fig. 397, B) has the middle toe much the largest, though the lateral toes still reach the ground.

In the later Miocene and earlier Pliocene we find the genus *Hipparion*, in which the foot is still three-toed (fig. 397, C); but the middle toe is alone functionally useful, the two lateral toes, though appearing externally, not being long enough to touch the ground.

In the later Pliocene we meet with the genus *Pliohippus*, in which the foot is precisely that of *Equus*, with the lateral toes reduced to splint-bones (fig. 397, D), but there is an additional præmolar, and an "antorbital fossa" is present. Lastly, in the Post-pliocene appears the genus *Equus* itself.

ARTIODACTYLE UNGULATES.

SECTION B. ARTIODACTYLA.—In this section of the Ungulates *the number of the toes is even—either two or four—and the third toe on each foot forms a symmetrical pair with the fourth* (fig. 388, C). *The dorso-lumbar vertebræ are nineteen in number, and there is no third trochanter on the femur. If true horns are present, these are always in pairs, and are supported by bony horn-cores. The antlers of the Deer are also paired, but they are not to be regarded as true horns. The stomach is always more or less complex, or is divided into separate compartments, and the cæcum is comparatively small and simple.* By Kowalewsky the *Artiodactyla*, recent and extinct, are divided into two great groups or sections, in accordance with the nature of the teeth. These two sections were differentiated at a very early period, and they are known respectively as the *Bunodonta* and *Selenodonta*. In the "Bunodont" section are comprised only the Pigs and their allies, and the Hippopotamus, in all of which the molars and præmolars have tuberculated crowns (fig. 398). In the "Selenodont" section of the *Artiodactyla* the præmolars and molars (fig. 399) have the grinding-surfaces of their crowns divided each into two crescentic lobes, the convexities of which are turned inwards in the upper and outwards in the lower teeth. Some fossil forms, which are otherwise allied to the Bunodont Artiodactyles, show teeth of a "selenodont" character, and thus form a transition between these otherwise sharply separated divisions of even-toed Ungulates.

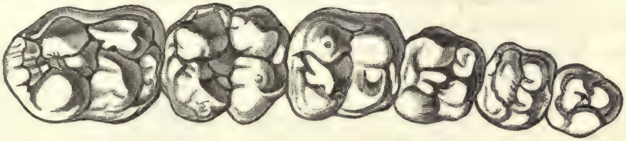

Fig. 398.—Grinding-surface of the molar and præmolar teeth of a Peccary (*Dicotyles labiatus*), showing the bunodont type of dentition. (After Giebel.)

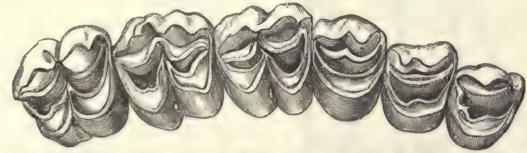

Fig. 399.—Grinding-surface of the molar and præmolar teeth of the Giraffe (*Camelopardalis Giraffa*), showing the selenodont type of dentition.

The section *Artiodactyla* comprises the Hippopotamus, the Pigs, and the whole group of the Ruminants, including Oxen, Sheep, Goats, Antelopes, Camels, Llamas, Giraffes, Deer, &c.

Besides these there is an extensive series of fossil forms commencing in the Eocene or Lower Tertiary period, and in many respects filling up the gaps between the living forms.

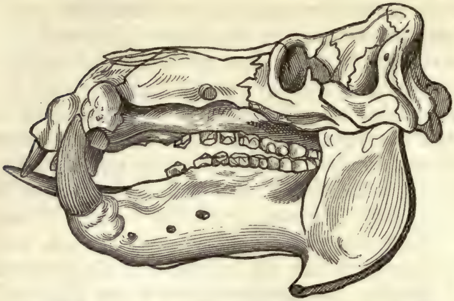

Fig. 400.—Skull of *Hippopotamus amphibius*, side-view. (After Giebel.)

OMNIVORA.

Fam. 1. *Hippopotamidæ.* — This group contains only the single genus *Hippopotamus*, characterised by the massive heavy body, the short blunt muzzle, the large head, and the presence of teeth of three kinds in both jaws (fig. 400). The dental formula of the living *Hippopotamus amphibius* is—

$$i\ \frac{2-2}{2-2};\ \ c\ \frac{1-1}{1-1};\ \ pm\ \frac{4-4}{4-4};\ \ m\ \frac{3-3}{3-3} = 40.$$

The incisors are nearly horizontal, those of the centre of the lower jaw being long and tusk-like. The canines are greatly developed, those of the upper jaw being comparatively short, while the lower canines are in the form of enormous tusks, with a chisel-shaped edge. The crowns of the præmolars and molars exhibit a characteristic double-trefoil pattern. The legs are very short, with massive feet, terminated by four hoofed toes each (fig. 401). The eyes and ears are small, and the skin is extremely thick, and is furnished with few hairs. The tail is very short.

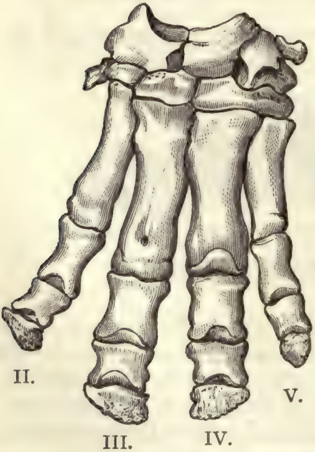

Fig. 401.—Left fore-foot of *Hippopotamus amphibius*. (After Cuvier.)

Several extinct species of *Hippopotamus* are known; but there is only one familiar living form, the *Hippopotamus amphibius* or River-horse, and this is confined to the African continent. It is an enormously bulky and unwieldy animal, reaching a length of eleven or twelve feet. It is nocturnal in its habits, living upon grass, the foliage of trees, and herbs, and it swims and dives with great facility. It is found in tolerable abundance in the rivers of Abyssinia, and occurs plentifully in South Africa. A much smaller form (the so-called *Hippopotamus* or *Chæropsis Liberiensis*) occurs on the west coast of Africa, but it is exceedingly rare, and comparatively little is known about it. It possesses, however, only two lower incisors instead of four.

Fam. 2. *Suida.*—The group of the *Suida*, comprising the Pigs, Hogs, and Peccaries, is very closely allied to the preceding; but the feet (fig. 388) have only two functional toes, the other two toes being much shorter, and hardly touching the ground. All the three kinds of teeth are present, but they vary a good deal. The canines (fig. 402) always are very large, and trihedral in shape; and in the males they usually constitute formidable tusks projecting from the sides of the mouth. The incisors are variable, but the lower ones are always inclined forwards. The molars and præmolars have broad crowns, with two transverse ridges (increased to three or more in the last molar), which are divided into rounded tubercles (fig. 398). The permanent dental formula of the Boar (*Sus scrofa*) is—

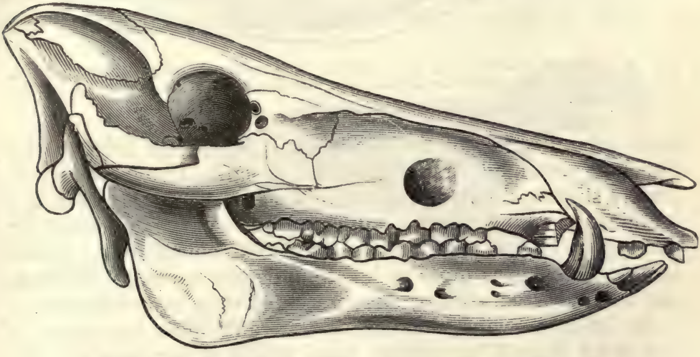

Fig. 402.—Skull of the Wild Boar (*Sus scrofa ferus*). (After Gray.)

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{3-3}{3-3};\quad m\,\frac{3-3}{3-3} = 40.$$

In the young animal there are four deciduous molars, but the first of these is not replaced by a præmolar, though it remains in the jaw up to the third year of life. If, therefore, the jaw of a Pig up to the third year of its age (fig. 403) be examined, there will appear to be four præmolars and three molars on each side, the first of these apparent præmolars being really the long-retained first deciduous molar. The stomach is mostly slightly divided, and is not nearly so complex as in the Ruminants. The snout is truncated and cylindrical, fitted for turning up the ground, and is capable of considerable movement. The skin is more or less abundantly covered with hair, and the tail is very short, or represented only by a tubercle.

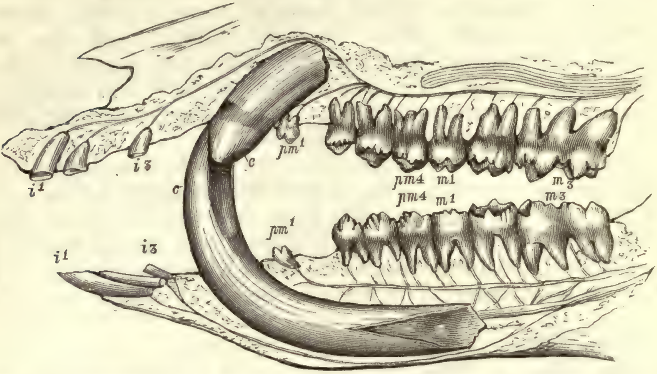

Fig. 403.—Dentition of the Boar (*Sus scrofa*). The tooth marked *pm*^{1}, though taking the place of a first præmolar, is really the first deciduous molar, which has not yet been shed.

Of the true Swine, the best known and most important is the Wild Boar (*Sus scrofa*), from which it is probable that most of our domestic varieties of swine have sprung. The Wild Boar formerly inhabited this country, and is still abundant in many of the forests of Europe. It is often hunted, and the size and sharpness of its canines render it a tolerably formidable adversary, as is also its congener, the Indian Hog (*Sus Indicus*). Another curious form, closely related to the Wild Boar, is the Babyroussa (*Porcus Babirusa*), which inhabits the islands of Celebes and Borneo in the Melanesian province. It is remarkable for the great size and backward curvature of the upper canines. The upper canines pierce the upper lip in the males, and their alveoli are directed upwards. The Bush-hogs (*Potamochœrus*) of Southern Africa and Madagascar are nearly allied to *Sus*, but possess subocular excrescences of a cartilaginous nature.

The African Wart-hogs, forming the genus *Phacochœrus*, are distinguished by having a fleshy wart under each eye. They inhabit Abyssinia, the Guinea coast, and other parts of Africa. The American Peccaries (*Dicotyles*) represent the Swine of the Old World. They are singular for having only three toes on the hind-foot, the outer of the two supplemental digits being represented only by its metatarsal. The canines are not exserted, there are only four upper incisors, and there is no tail. They are exclusively confined to the American continent, extending from Paraguay as far north as Texas and Arkansas, and the commonest species is the Collared Peccary (*Dicotyles torquatus*). They are not at all unlike small pigs either in their appearance or in their habits, and they are gregarious, generally occurring in small flocks.

Fam. 3. *Anoplotheridæ.*—This group comprises extinct Artiodactyles which belong to the Eocene and Miocene periods, and form a kind of transition between the Swine and the Ruminants. In *Anoplotherium* itself (fig. 404) the body is slender, provided with a long tail, and having the feet terminated by two toes each, sometimes with small accessory hoofs in addition. The dentition is remarkable in the fact that no gap or diastema exists between the molars and the canines, the teeth thus forming an even and uninterrupted series. The dental formula is—

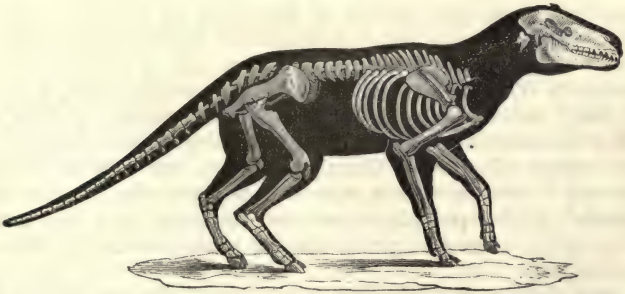

Fig. 404.—*Anoplotherium commune.* Eocene Tertiary, France. (After Cuvier.)

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{4-4};\quad m\,\frac{3-3}{3-3} = 44.$$

Fam. 4. *Oreodontidæ.*—This family comprises extinct Artiodactyles from the Miocene and Pliocene Tertiary of North America, which stand in some respects midway between the

Suida and the *Ruminantia*, and have been termed "Ruminating Hogs," though there is no evidence that they really ruminated. *Oreodon* is about as big as a sheep, the feet being four-toed, and the dental formula "complete." The canines are large, and triangular, and the molars are of the "selenodont" character, while there is the anomalous character that "larmiers" or "tear-pits" existed below the eyes.

RUMINANTIA.

The last section of the *Artiodactyle* Ungulates is the great and natural group of the *Ruminantia*, or Ruminant animals. This section comprises the Oxen, Sheep, Antelopes, Giraffes, Deer, Camels, &c., and is distinguished by the following characters:—

The foot is what is called "cloven," consisting of a symmetrical pair of toes encased in hoofs and looking as if produced by the splitting into two equal parts of a single hoof. In addition to these functional toes, there are mostly two smaller supplementary toes, placed at the back of the foot. The metacarpal bones of the two functional toes of the fore-limb, and the metatarsal bones of the same toes of the hind-limb, except in *Hyomoschus*, coalesce to form a single bone, known as the "canon-bone." The stomach is complex, and is divided into several compartments, this being in accordance with their mode of eating. They all, namely, ruminate or "chew the cud"—that is to say, they first swallow their food in an unmasticated or partially-masticated condition, and then bring it up again, after a longer or shorter time, in order to chew it thoroughly.

This process of rumination is so characteristic of this group, that it will be necessary to describe the structure of the stomach, as showing the mechanism by which this singular process is effected. The stomach (fig. 405) is divided into four (rarely three) compartments, which are usually so distinct from one another that they have generally been spoken of as so many separate stomachs. The gullet opens at a point situated between the first and second of these cavities or "stomachs." Of these the largest lies on the left side, and is called the "rumen" or "paunch" (fig. 405, *r*). This is a cavity of very large capacity, having its interior furnished with numerous hard papillæ or warts. It is the chamber into which the food is first received when it is swallowed, and here it is moistened and allowed to soak for some time. The second stomach, placed to the right of the paunch, is much smaller, and is known as the "reticulum" or "honeycomb-bag" (*h*). Its inner surface is reticulated, or is divided by ridges into a number of hexagonal or many-sided cells, somewhat resembling the cells of a honeycomb. The reticulum is small and globular, and it receives the food after it has lain a sufficient time in the paunch. The function of the reticulum, as usually believed, is to compress the partially-masticated food into little balls or pellets, which are then returned to the mouth by a reversed action of the muscles of the œsophagus; but this is now discredited. After having been thoroughly chewed and prepared for digestion, the food is swallowed for the second time. On this occasion, however, the triturated food passes on into the third cavity (*p*), which is variously known as the "psalterium," "omasum," or (*Scotticé*) the "manyplies." The vernacular and the first of these technical names both refer to the fact that the inner lining of this cavity is thrown into a number of longitudinal folds, which are so close as to resemble the leaves of a book. The psalterium opens by a wide aperture into the fourth and last cavity, the "abomasum" (*a*), both appearing to be divisions of the pyloric portion of the stomach. The mucous membrane of the abomasum is thrown into a few longitudinal folds, and it secretes the true acid gastric juice. It terminates, of course, in the commencement of the small intestine—*i.e.*, the duodenum. The intestinal canal of Ruminants, as in most animals which live exclusively upon a vegetable diet, is of great relative length.

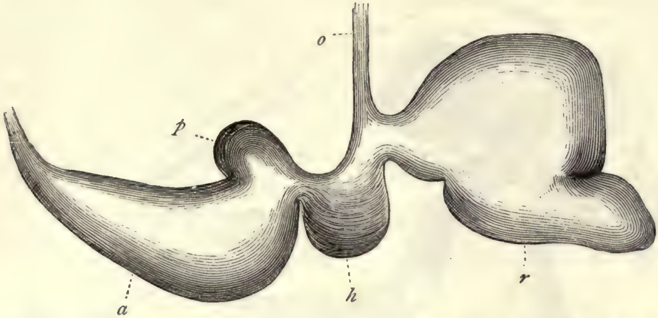

Fig. 405.—Stomach of a Sheep: *o* Gullet; *r Rumen* or Paunch; *h* Honeycomb-bag or *Reticulum*; *p* Manyplies or *Psalterium*; *a* Fourth Stomach or *Abomasum.*

The dentition of the Ruminants presents peculiarities almost as great and as distinctive as those to be derived from the digestive system. In the typical Ruminants (*e.g.*, Oxen, Sheep, Antelopes) there are no incisor teeth in the upper jaw, their place being taken by a callous pad of hardened gum, against which the lower incisors impinge (fig. 406). There are also no upper canine teeth, and the only teeth in the upper jaw are six grinders on each side. In the front of the lower jaw is a continuous and uninterrupted series of eight teeth, of which the central six are incisors, and the two outer ones are regarded by Owen as being canines. Upon this view, canine teeth are present in the lower jaw of the typical Ruminants, and they are only remarkable for being placed in the same series as the incisors, which they altogether resemble in shape, size, and direction. Behind this continuous series of eight teeth in the lower jaw, there is a vacant space, which is followed behind by six grinders on each side. The præmolars and molars are of the "selenodont" type (fig. 399), and have their grinding-surfaces marked with two double crescents, the convexities of which are turned inwards in the upper, and outwards in the lower teeth.

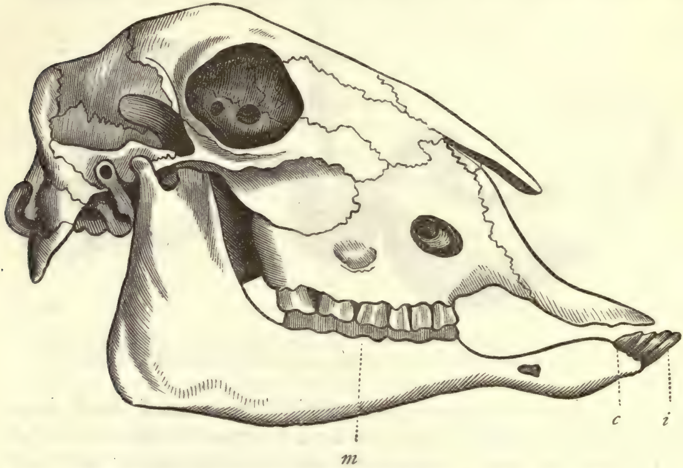

Fig. 406.—Skull of a hornless Sheep: *i* Incisors; *c* Canines; *m* Molars and præmolars. (After Owen.)

The dental formula, then, for a typical Ruminant animal, is—

$$i\,\frac{0-0}{3-3};\ \ c\,\frac{0-0}{1-1};\ \ pm\,\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3} = 32.$$

The departures from this typical formula occur in the *Camelidæ*, the *Tragulidæ*, and in some of the Deer. Most of the Deer conform in their dentition to the above formula, but a few forms (*e.g.*, the Muntjak) have canine teeth in the upper jaw. These upper canines, however, are mostly confined to the males; and if they occur in the females, they are of a small size. The dentition of the *Camelidæ* (Camels and Llamas) is still more aberrant, there being two canine-like upper incisors and upper canines as well. The lower canines also are more pointed and stand more erect than the lower incisors, and slightly separated from them, so that they are easily recognisable. The group of the *Ruminantia* includes the families of the *Camelidæ* (Camels and Llamas), the *Tragulidæ* (Chevrotains), the *Cervidæ* (Deer), the *Camelopardalidæ* (Giraffe), and the *Cavicornia* (Oxen, Sheep, Goats, Antelopes).

a. Camelidæ (*Tylopoda*).—The Camels and Llamas constitute in many respects an aberrant group of the *Ruminantia*, especially as regards their dentition and the conformation of the feet. The upper jaw (fig. 407) carries three teeth on each side in front, separated by slight intervals. The most anterior of these is a conical incisor; the central one is a canine, and the hindmost is the first præmolar, which is separated by a wide gap from the rest of the molar series, and is pointed in form. In the lower jaw there is also a canine, placed a little behind the incisors, and a detached laniariform præmolar (the latter sometimes absent). In the Llamas these isolated præmolars do not exist. Each foot terminates in two toes, which are provided with imperfect nail-like hoofs, covering no more than the upper surface of each toe. The two hinder toes, which are mostly present in the Ruminants, are here altogether wanting, and the animal walks upon the hinder surfaces of the toes,

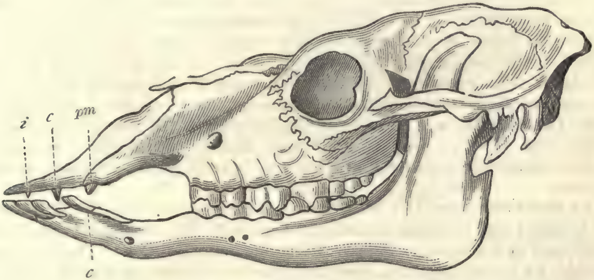

Fig. 407.—Side-view of skull of *Camelus Bactrianus*: *i* Upper incisor; *c c* Canines; *pm* Isolated præmolar. (After Giebel.)

which are directed downwards, and are protected by pads of callous horny integument. The stomach is complex, but the manyplies is wanting. As regards their further characters, the head of all the *Camelidæ* is destitute of horns in both sexes; the nostrils can be closed at the will of the animal; the upper lip is hairy and partially cleft; and the red blood-corpuscles are oval.

The family of the *Camelidæ* is represented in the Old World by the Camels (*Camelus*), and in South America by the Llamas and Alpacas (*Auchenia*). There is also an extensive series of Tertiary forms, one of which (viz., *Protolabis*) is specially interesting as possessing the full number of upper incisors, namely, three on each side of the jaw.

The true Camels are peculiar to Asia and Africa, and two species are known, distinguished from one another by the possession of a double or single adipose hump on the back. The African or Arabian Camel (*Camelus Dromedarius*) is often called the Dromedary, and has only one hump on its back. The two toes are united together by the callous sole; and the chest, shoulders, and knees are furnished with callous pads, upon which they rest when they lie down. The hump is almost entirely composed of fat, and appears to act as a kind of reserve supply of food, as it is noticed to diminish much in size upon long journeys. The Camel can likewise support a very prolonged privation of water, as the paunch is furnished with large cells, which the animal fills when it has access to water, and then makes use of subsequently as occasion may require. The structure of the Camel adapts it admirably for locomotion in the sandy deserts of Arabia and Africa; and as it is very docile and good-tempered, it is almost exclusively employed as a beast of burden in the countries in which it occurs.

The Bactrian Camel (*C. Bactrianus*) is distinguished by the possession of two humps; but in other respects it does not differ from the Dromedary. It is found in Turkestan, Persia, Mongolia, and Thibet. The two species are said to breed together, and the hybrid offspring is stated to be occasionally fertile. The place of the Camels is taken in the New World by the Llama and Alpaca, with two other nearly-allied forms. These animals form the genus *Auchenia*, and are in many respects similar to the true Camels. They are distinguished, however, by having no hump upon the back, and by the fact that the two toes are not conjoined and supported by a callous pad, as in the Camels, but are separate, with separate pads, and with strong curved nails. The neck is long and the head comparatively small, whilst the upper lip is mobile and deeply cleft vertically. The Llamas are chiefly found in Peru and Chili. They live in flocks in mountainous regions, and are much smaller than the Camels in size. The true Llama is kept as a domesticated animal, and used as a beast of burden, its wild form being known as the "Guanaco." The Alpaca is still smaller than the Llama, and is not very unlike a sheep, having a long woolly coat. It is partially domesticated, and the wool is largely imported into Europe. Its wild form is the so-called "Vicuna."

b. Tragulidæ.—This group comprises certain small Ruminants, the so-called "Chevrotains" (*Tragulus*), which have been generally associated with the true Musk-deer (*Moschus*) in a single family, under the name of *Moschidæ.* The researches of Milne-Edwards and Flower, however, would prove that *Moschus* itself is really one of the *Cervidæ* or Deer proper, and that the Chevrotains form a group by themselves.

The *Tragulidæ* are characterised by the total absence of horns in both sexes, and by the presence of canines in both jaws, those in the upper jaw being in the form of tusks in the males, but much smaller in the females. The third stomach, or "psalterium," is wanting, and the placenta is diffuse. The feet have supplementary toes, and the metacarpals of the middle and ring digits either unite in late life to form a canon-bone, or remain (as in *Hyomoschus*) permanently separate.

The family includes at the present day only the *Hyomoschus* of Western Africa, and some four or five species of *Tragulus* from the Indian province. The best known are the *Tragulus Javanicus*, or "Napu" of Java, and the *T. meminna* of India. They are all very small elegant animals, and, though commonly called "Musk-deer," they have no musk-gland.

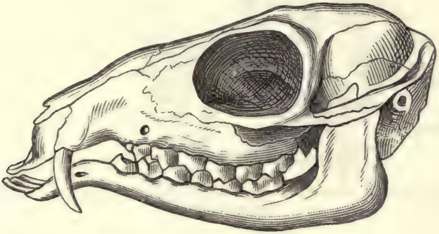

Fig. 408.—Side-view of the skull of *Tragulus Javanicus.* (After Giebel.)

c. Cervidæ.—This family is of much greater importance than that of the *Tragulidæ*, including as it does all the true Deer. They are distinguished from the other Ruminants chiefly by the nature of the horns, which are wanting in the genera *Moschus*, *Hydropotes*, and *Lophotragus.* With the single exception of the Reindeer, these appendages are confined to the males amongst the *Cervidæ*, and do not occur in the females. They do not consist, as in the succeeding group, of a hollow sheath of horn surrounding a central bony core, nor are they permanently retained by the animal. On the other hand, the horns —or, as they are more properly called, the *antlers*—of the *Cervidæ* are deciduous, and are solid. They are bony throughout, and are usually more or less branched (fig. 410), and they are annually shed and annually reproduced at the breeding season. They increase in size and in the number of branches every time they are reproduced, until in the old males they may attain an enormous size. The antlers are carried upon the frontal bone, and are produced by a process not at all unlike that by which injuries of osseous structures are made good in man. At first the antlers are covered with a sensitive hairy skin or "velvet"; but as development proceeds, the vessels of the skin are gradually obliterated, and the skin dies and peels off; a bony ridge or "burr" being formed on the antler just above its base of attachment to the frontal bone.

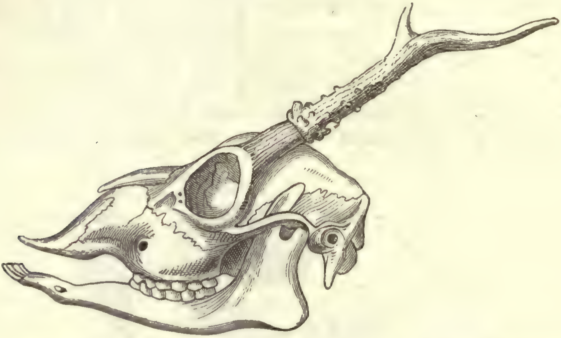

Fig. 409.—Side-view of the skull of the Roebuck (*Capreolus capræa*). (After Giebel.)

In all the Deer there is a sebaceous gland, called the "lachrymal sinus," or "larmier," which is placed beneath each eye, and secretes a strongly-smelling waxy substance.

When fully developed, the antlers of the Deer consist of a main stem or "beam," carrying one or more branches or "tynes." In the second year after birth, when the antlers are first produced, and in a few Deer throughout life, the antler consists only of the "beam," and is dagger-shaped and unbranched, the animal being known now as a "brocket." In the horns of the next year, the antler develops a basal branch or "brow-tyne." In the antlers of the next year there is produced above the brow-tyne a second branch or "tres-tyne," which is directed forwards, the hinder portion of the beam constituting the "royal." If the antler develops beyond this point, it is by the more or less complex branching of these two divisions of the beam, the "royal tyne," in particular, being very liable to become divided in successive years. The following are the principal types of antlers among the Deer:—

(A.) *Rusine type.*—The brow-tyne simple, the beam simply divided (fig. 410, A). This form of antler occurs in the Sambur Deer (*Rusa Aristotelis*) and in the Axis Deer of India.

(B.) *Rucervine type.*—The two primary divisions of the beam above the brow-tyne again bifurcated, and both divisions approximately equal, as in the *Rucervus Schomburgki* of Siam (fig. 410, B). In a modification of this type, the royal tyne is reduced in size (fig. 410, C), and the tres-tyne is large; while in a still more extreme type, the royal tyne is reduced to a mere snag.

(C.) *Elaphine type.*—Brow-tyne reduplicated (by the presence of a "bez-tyne"); the royal tyne large and divided. This type occurs in the Red Deer (*Cervus elaphus*, fig. 410, F and G). In the "sub-elaphine" type (as in the *Cervus sika* of Japan), the brow-tyne is simple.

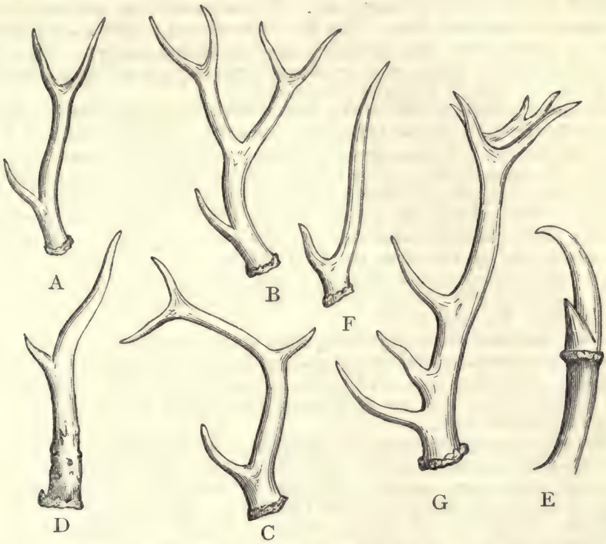

Fig. 410.—A, Antler of the "Rusine" type (Sambur Deer); B, Antler of the "Rucervine" type (*Rucervus Schomburgki*); C, Modified Rucervine type of Antler (*Rucervus Duvaucelli*) in which the "royal" tyne is reduced in size; D, Antler of the "Capreoline" type (*Capreolus capræa*); E, Antler of the Muntjak (*Cervus muntjak*); F, Antler of the Red-deer (*Cervus elaphus*) of the second year; G, Antler of the full-grown Red-deer, showing the "elaphine" type.

(D.) *Capreoline type.*—The beam dividing into a short anterior and a longer posterior branch, the latter, when fully developed, again bifurcated at its extremity (fig. 410, D). This type of antler occurs in the Roebuck (*Capreolus capræa*).

(E.) *Type of the Muntjak.*—Antler supported upon an osseous pedicle arising from the frontal bone; a short brow-tyne; the beam undivided. Occurs only in the Muntjak (*Cervus muntjak*).

The *Cervidæ* are very generally distributed, but no member of the group has hitherto been discovered in either Australia or South Africa, their place in the latter continent seeming to be taken by the nearly-allied Antelopes (distinguished by their hollow horns). Africa, in fact, has no Deer except the Barbary Deer alone, and this occurs north of the Sahara only.

Very many species of *Cervidæ* are known, and it is not possible to allude to more than a few of the more familiar and important forms. Three species occur in Britain—namely, the Roebuck, Red-deer, and Fallow-deer, the last being a doubtful native. The Roebuck (*Capreolus capræa*) was once very generally distributed over Britain, but is almost confined to the wilder parts of Scotland at the present day. It is of small size, and ranges over Northern Europe and Asia. The Red-deer or Stag (*Cervus elaphus*) is a much larger species, with well-developed spreading antlers. The Red-deer of Britain is represented in North America by a still larger species, known as the Wapiti (*Cervus Canadensis*).

The third British species is the Fallow-deer (*Dama platyceros*), characterised by the fact that the antlers are palmated—that is, dilated towards their extremities. It is a doubtful native, and is never found in a wild state at the present day. Allied to the Fallow-deer is a gigantic extinct species, the *Megaceros Hibernicus*, which inhabited Ireland, the Isle of Man, Scotland, and probably the greater part of Europe, up to a comparatively modern date, probably having survived into the human period. It is often, but incorrectly, spoken of as the Irish "Elk," but it is really a genuine Stag. The animal was of very great size, and was furnished with enormous spreading and palmate antlers, which measure from ten to twelve feet between the tips.

Of all the Deer, the largest living form is the true Elk (*Alces palmatus*), which is generally distributed over the northern parts of Europe, Asia, and America, being often spoken of as the Moose. The antlers in the Elk are of a very large size, and are very broad, terminating in a series of points along their outer edges.

The only completely domesticated member of the *Cervidæ* is the Reindeer (*Cervus tarandus*), which is remarkable for the fact that the female is furnished with antlers similar to, but smaller than, those of the males. At the present day the Reindeer (if the Caribou be regarded as distinct) is exclusively confined to the extreme north of Europe and Asia, abounding especially in Lapland. Remains, however, of the Reindeer are known to occur over the greater part of Europe, extending as far south, at any rate, as the Alps, and occurring also in Britain. From this fact, taken along with many others, the existence of an extremely cold climate over the greater part of Europe at a comparatively recent period may be safely inferred. The Reindeer lives chiefly upon moss and a peculiar kind of lichen (*Lichen rangiferina*), and they are extensively used by the Laplanders both as beasts of burden and as supplying food. The "Caribou" of North America, if not absolutely identical with the Reindeer, would seem to be at most a well-marked variety of it.

The so-called "Brockets," such as the "Guazu-pita" (*Subulo rufus*) of South America, have simple horns in the form of a stiletto; whilst the singular Muntjak of India, Burmah, China, and the Indian Archipelago has the horns supported on long bony pedicles springing from the frontal bone; and the males have large upper canines.

The true Musk-deer (*Moschus moschiferus*) possess no horns, and the males have a musk-gland. There are canine teeth in both jaws, and the upper canines of the males have the form of long tusks. The Musk-deer are elegant little animals, which agree with the typical Deer in the fact that they have spotted young, and that the placenta is cotyledonary, whilst they depart from the ordinary cervine type in the absence of antlers. They inhabit Central Asia.

The curious Water-deer (*Hydropotes*) of China is related to *Moschus*, and also has no horns. Another curious Chinese form is the *Elaphurus*, in which there is a long tufted tail, and the antlers, in place of an anterior basal branch, possess a long posterior branch, the end of which is dilated and prolonged into several short points.

d. Camelopardalidæ. — This family includes only a single living animal—the *Camelopardalis Giraffa*, or Giraffe—sometimes called the Camelopard, from the fact that the skin is spotted like that of the Leopard, whilst the neck is long, and gives it some distant resemblance to a Camel. There are no upper canines in the Giraffe, and both sexes possess two small frontal horns, which, however, are persistent, and remain permanently covered by a hairy skin, terminated by a tuft of long stiff bristles. These are not mere out-growths of the frontals, but are independent ossifications placed on the sutures between the frontal and parietal bones. There is also a central horn, if it may be so called, which is of the nature of an epiphysis, and is placed upon the sagittal suture. It becomes early anchylosed with the skull, as do ultimately the other two horns. The neck is of extraordinary length, but, nevertheless, consists of no more than the normal seven cervical vertebræ. The fore-legs appear to be much longer than the hind-legs, and all are terminated by two toes each, the supplementary toes being altogether wanting. The tongue is very long and movable, and is employed in stripping leaves off the trees. The Giraffe is the largest of all the Ruminants, measuring as much as from fifteen to eighteen feet in height. It is a harmless and inoffensive animal, but defends itself very effectually, if attacked, by kicking. It is found in Nubia, Abyssinia, and the Cape of Good Hope.

Remains of gigantic Ruminants allied to the Giraffe have been found in France and Greece (*Helladotherium*); but the *Sivatherium*, sometimes referred to this family, appears to have been more nearly allied to the true Antelopes.

e. Cavicornia.—The last family of the Ruminants is that of the *Cavicornia*, comprising the Oxen, Sheep, Goats, and Antelopes. This family includes the most typical Ruminants, and those of most importance to man. The upper jaw in all the *Cavicornia* is wholly destitute of incisors and canines, the place of which is taken by the hardened gum, against which the lower incisors bite. There are six incisors and two canines in the lower jaw, placed in a continuous series, and the molars are separated by a wide gap from the canines. There are six grinders on each side of each jaw. Both sexes have horns, or the males only may be horned, but in either case these appendages are very different to the "antlers" of the *Cervidæ*. The horns, namely, are persistent, instead of being deciduous, and each consists of a bony process of the frontal bone—or "horn-core"—covered by a sheath of horn (fig. 411). In the Prong-buck (*Antilocapra*), however, the *sheath* of the horn is shed annually. The feet are cleft, but are mostly furnished with accessory hoofs placed on the back of the foot.

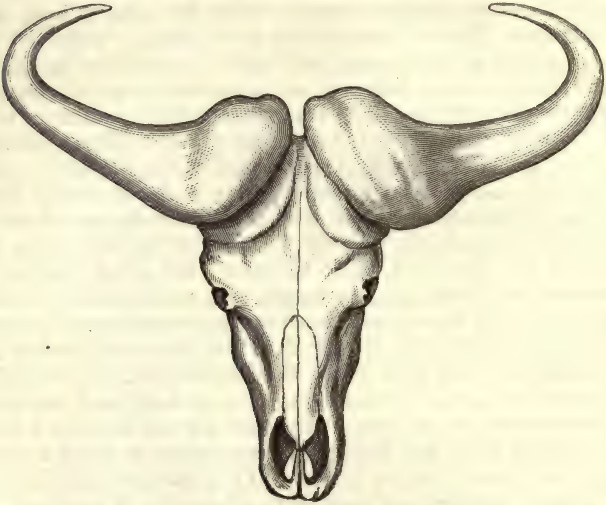

Fig. 411.—Skull of the Cape Buffalo (*Bubalus caffer*), viewed from above, showing the horn-cores. (After Cuvier.)

The *Cavicornia* comprise the three families of the *Antilopidæ*, *Ovidæ*, and *Bovidæ*. The Antelopes form an extremely large section, with very many species. They are characterised by their slender deer-like form, their long and slender legs, and their simple cylindrical annulated or twisted horns, which are sometimes confined to the males, but often occur in the females as well (fig. 412). Accessory hoofs are generally, but not always, present. The Antelopes must on no account be confounded with the true Deer, to which they present many points of similarity. The structure of the horns, however, is quite sufficient to distinguish them. The Antelopes are further distinguished by rarely having a beard or dew-lap, and by the general possession of "inguinal pores" and "lachrymal sinuses." The inguinal pores are the apertures of two involutions of the integument of the groin, secreting a viscous substance, the use of which is unknown. The lachrymal sinuses, or "tear-pits," have already been mentioned as occurring in the *Cervidæ*, and are not found in any of the *Cavicornia* except the Antelopes.

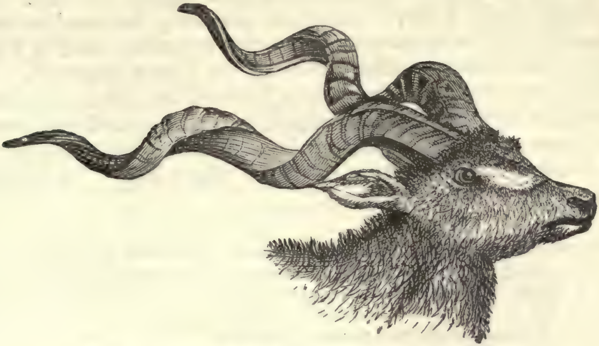

Fig. 412.—Head of the Koodoo (*Strepsiceros Koodoo*).

Each consists of a sebaceous sac placed beneath the eye, and secreting a yellowish waxy substance. The function of these glands is uncertain, but it is probably sexual. The Antelopes are especially numerous, both in individuals and in species, in Africa, in which country they appear to take the place of the true Deer (only one species of Deer being indigenous to Africa). Amongst the better-known African species of Antelopes are the Springbok, Hartebeest, Gnu, Eland, and Gazelle. The only European Antelopes are the Chamois (*Rupicapra tragus*), which inhabits the Alps and other mountain-ranges of southern Europe, and the Saiga of eastern Europe. Amongst the more remarkable Antelopes may be mentioned the Prong-buck (*Antilocapra Americana*) of N. America, in which there are no accessory hoofs, lachrymal sinuses, or inguinal pores; the females have very small horns, and the horns of the male have a snag or branch in front. The horn-core, however, is conical, and does not extend above the snag. The horns are also very remarkable for the fact that their sheath is annually shed, and annually reproduced. Another curious form is the Chickara (*A. quadricornis*) of India, in which the females are hornless, but the males have four horns.

The Sheep and Goats (*Ovidæ*) have mostly horns in both sexes, and the horns are generally curved, compressed, and turned more or less backwards. The body is heavier, and the legs shorter and stouter, than in the true Antelopes. In the true Goats (*Capra*) both sexes have horns, and there are no lachrymal sinuses. The throat is furnished with long hair, forming a beard; and this appendage is usually present in both sexes, though sometimes in the males only. The goats live in herds, usually in mountainous and rugged districts. The domestic Goat (*Capra hircus*) is generally believed to be a descendant of a species which occurs in a wild state in Persia and in the Caucasus (the "Paseng," or *Capra ægagrus*). The true Sheep (*Ovis*) are destitute of a beard, and the horns though triangular and transversely ridged, are more cylindrical than in the Goats, and are generally twisted into a spiral. Horns may be present in both sexes, or in the males only.* Lachrymal sinuses are invariably absent.

Numerous varieties of the domestic sheep (*Ovis aries*) are known, but it is not certainly known from what wild species these were originally derived. Some, at any rate, of the domesticated breeds, more especially the smaller short-tailed breeds, with crescent-shaped horns, appear to be descended from the wild species known as the "Moufflon," which is found in Corsica and Sardinia. The Merino Sheep (a Spanish breed) and the Thibet Sheep are particularly celebrated for their long and fine wool. With the exception of one species (the Big-horn, *Ovis montana*), all the Sheep appear to be originally natives of the Old World. The Big-horn, however, inhabits the Rocky Mountains from their termination in latitude 68° to 40°.

The true Oxen (*Bovidæ*) are distinguished by having simply rounded horns, which are not twisted in a spiral manner. There are no lachrymal sinuses. Most of the oxen admit of being more or less completely domesticated, and some of them are amongst the most useful of animals, both as beasts of burden and as supplying food.

The parent stock of our numerous breeds of cattle is not known with absolute certainty; the nearest approach to British Wild Cattle being a celebrated breed which is still preserved in one or two places. These "Chillingham Cattle" are a fine wild breed, which at one time doubtless existed over a considerable part of Britain. They are pure white, with a black muzzle, the horns white, tipped with black. Though degenerate in point of size, the Chillingham Cattle are probably the descendants of the "mountain-bull" or "Urus," which existed in a wild state in Gaul at the time of Cæsar's invasion. The smaller breeds of European Cattle appear to be descended from a now extinct species, the "British Short-horn" (*Bos longifrons*). Another large Ox, which formerly existed in Britain, and abounded over the whole of Europe, is the Aurochs or Lithuanian Bison (*Bos bison*). The Aurochs is of very large size, considerably exceeding the common Ox in bulk. It still occurs in the forests of the Caucasus in a wild state, but it no longer occurs wild in Europe, if we except a herd maintained by the Czar in one of the forests of Lithuania.

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* In the Merino Sheep, and in some other breeds also, the males only are horned.

Nearly allied to the Aurochs is the American Bison or Buffalo (*Bison Americanus*). This species formerly occurred in innumerable herds in the prairies of North America, but it has been gradually driven westwards, and has been much reduced in numbers. It has an enormous head, a shaggy mane, and a conical hump between the shoulders. Two other very well known forms are the Cape Buffalo (*Bubalus caffer*) and the common Buffalo (*Bubalus bubalis*). The former of these occurs, with two allied forms, in southern and eastern Africa, and the latter is domesticated in India and in many parts of the south of Asia. The horns in both species are of large size, and their bases are confluent, so that the forehead is protected by a bony plate of considerable thickness.

Amongst the more remarkable Asiatic Oxen may be mentioned the Zebu (*Bos Indicus*) distinguished by the fatty hump over the withers at the back of the neck, and the Yak (*Poephagus grunniens*) of Thibet, remarkable for its long silky tail, and the possession of a fringe of long hair along its shoulders, flanks, and thighs. The "humped" Cattle of the East are almostly certainly descended from a stock different to that which has given origin to the humpless races. They are known from Egyptian monuments to have been domesticated at an extremely early period; but their wild form is unknown.

The last of the Oxen which deserves notice is the curious Musk-ox (*Ovibos moschatus*). This singular animal is at the present day a native of Arctic America, north of latitude 60°, and is remarkable for the great length of the hair. It is called the Musk-ox, because it gives out a musky odour. Like the Reindeer, the Musk-ox had formerly a much wider geographical range than it has at present; the conditions of climate which are necessary for its existence having at that time extended over a very much larger area than at present. The Musk-ox, in fact, in Post-tertiary times is known to have extended over the greater part of Europe, remains of it occurring abundantly in certain of the bone-caves of France. Good authorities regard the Musk-ox as being a sheep, and therefore truly referable to the *Ovidæ*.

As regards the distribution of the *Ungulata* in *time*, the order is not known to have commenced its existence earlier than the Eocene Tertiary; but it presented itself throughout the whole Tertiary period under such numerous and such varied types that it will not be possible in this place to do more than simply indicate the geological range of the principal families.

Of the *Rhinocerotidæ*, hornless forms (*Acerotherium*) occur in Miocene and Pliocene strata; but the best-known fossil species is the two-horned Woolly Rhinoceros (*R. tichorhinus*). This curious species occurs in Post-pliocene deposits, and must have ranged over the greater part of Europe. It was adapted to a temperate climate, and, like the Mammoth, possessed a thick covering of mixed wool and hair. This has been demonstrated by the discovery of a frozen carcass in Siberia. The curious genus *Diceratherium*, with its transverse pairs of horns, is from the Miocene of North America.

The *Tapiridæ* are represented in the Eocene and Miocene by the genus *Lophiodon.* (*Coryphodon*, which has generally been placed here, has been shown by Marsh to have *five* toes to both feet, and it, therefore, forms the type of a special family of Perissodactyles.) The genus *Tapirus* itself begins in the Miocene.

The *Brontotheridæ* are wholly extinct, and are confined to the Miocene of North America.

The *Palæotheridæ* are likewise completely extinct, and are confined to the Eocene and Miocene.

The *Macrauchenidæ* are confined to the Pliocene and Postpliocene of South America.

The distribution of the *Equidæ* in time has already been spoken of (see p. 702). The oldest genus of the family is the *Eohippus* of the American Eocene.

Amongst the *Artiodactyles*, the earliest representative of the *Hippopotamidæ* is the *Hexaprotodon* of the Upper Miocene (Pliocene?) of India, which differs from *Hippopotamus* proper only in having six lower incisors, in place of four. The latter genus appears in Europe in the Pliocene.

A very large number of fossil forms of *Suida* are known from the Tertiaries of both the Old and New Worlds, beginning in the Eocene (*Chæropotamus*, &c.)

The *Oreodontidæ* are wholly confined to North America, and belong to the Miocene and Pliocene.

The *Anoplotheridæ* are wholly extinct, and are confined to the Eocene and Miocene periods.

The *Camelidæ* are first represented in the Miocene deposits of North America (*Poëbrotherium*, &c.), and the later Tertiaries and Post-tertiaries of the same country have yielded several other extinct types of this family. Fossil remains of *Camelidæ* also occur in the Upper Miocene (Pliocene?) of India; and early types of the Llamas occur in the Pliocene of South America.

The *Tragulidæ* are first known to have come into existence during the Miocene period (*Amphitragulus* and *Dremotherium*); but it is possible that some Eocene types (*Xiphodon* and *Cainotherium*) are really referable here.

The *Cervidæ* appear for the first time in the Miocene (*Dorcatherium*, *Dicrocerus*, &c.) *Cervus* itself appears in the Upper Miocene, and of the same age is the genus *Amphimoschus*, related to the living Musk-deer.

The first representative of the *Camelopardalidæ*, so far as known, is the *Helladotherium* of the Upper Miocene of France, Greece, and India.

The *Antilopidæ* appear in forms closely allied to recent ones in the Miocene of Europe; and in beds of Upper Miocene

(Pliocene?) age in India we have the aberrant four-horned types which constitute the genera *Sivatherium* and *Bramatherium.*

True *Bovidæ* occur in the Miocene (Pliocene?) of India, and the Pliocene of Europe, whilst *Ovidæ* resembling existing types are not known from deposits earlier than the Post-pliocene.

CHAPTER LXXIII.

DINOCERATA, TILLODONTIA, AND TOXODONTIA.

ORDER VII. DINOCERATA.—This order comprises certain extraordinary extinct Mammals from the Eocene of North America, which are regarded by Prof. Cope as an aberrant group of *Ungulates*, whilst Prof. Marsh considers them as a distinct order intermediate between the *Perissodactyle Ungulates* and the *Proboscidea.*

The members of this order are all of gigantic dimensions, and of massive construction. *Both the hind-feet and fore-feet possessed five well-developed toes. The nasal bones were elongated, and do not seem to have supported a proboscis. The cranium carries three pairs of horn-cores, which were probably enveloped in horny sheaths. There are no upper incisors, and the upper canines have the form of long tusks directed downwards.* (These characters are taken from *Dinoceras*, the best-known genus of the group.) The order is distinguished from the *Proboscidea* by the absence of upper incisors, the presence of canines, the possession of three pairs of horn-cores, and the absence of a proboscis.

In *Dinoceras* itself, which may be taken as the type of the group, we have a large animal equal in dimensions to the living Elephants, which it resembles also in the osteology of its limbs, in most essential respects. It is in the skull (fig. 413) and dentition, however, that the most striking peculiarities of *Dinoceras* are to be found. As regards the dentition, the front of the upper jaw was destitute of incisors, and probably carried a palatine pad, but there were two very large canines in the form of tusks directed perpendicularly downwards; and there was also a series of six small grinders on each side. In the lower jaw are six incisors, small canines, and twelve præmolars and molars, six on each side. The dental formula is thus—

$$i\,\frac{0-0}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{3-3}{3-3};\quad m\,\frac{3-3}{3-3}=34.$$

Superiorly each maxillary bone carried a well-developed process, probably of the nature of a horn-core. The nasals support two similar but smaller horn-cores; and the frontals are developed behind into two larger bony projections most probably also of the nature of horn-cores. The animal thus possessed three pairs of horns, one carried by the upper jawbones, one by the nasals, and one by the frontal bones; though it is possible that some of these cores were simply covered by a callous integument. The nasal bones are long, and there is no evidence of any proboscis. The limbs are short, the fore-legs shorter than the hind-legs; and the femur was not provided with a third trochanter. The tail is short and slender, and the ribs are furnished with rudimentary uncinate processes.

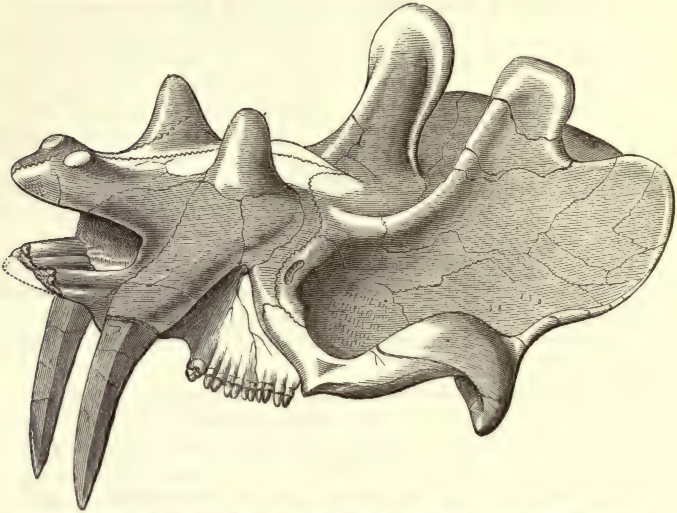

Fig. 413.—Skull of *Dinoceras mirabile*, after Marsh. From the Eocene Tertiary.

As regards the mental powers of *Dinoceras*, Prof. Marsh remarks: "The brain-cavity of *Dinoceras* is perhaps the most remarkable feature in this remarkable genus. It proves conclusively that the brain was proportionately smaller than in any other known Mammal, recent or fossil, and even less than in some reptiles. It is, in fact, the most reptilian brain in any known Mammal. In *D. mirabile*, the entire brain was actually so diminutive that it could apparently have been drawn through the neural canal of all the præsacral vertebræ, certainly through the cervicals and lumbars."

The chief genera which are included amongst the *Dinocerata* by Marsh are *Dinoceras*, *Tinoceras*, and *Uintatherium*. All the remains of this singular group which have hitherto been brought to light, are from the Eocene rocks of North America.

ORDER VIII. TILLODONTIA.—This order has been established by Prof. Marsh for the reception of some singular Mammals from the Eocene Tertiary of the United States. The following are the characters of the order, so far as published: *The molar teeth have grinding crowns, as in Ungulates, and may have distinct roots, or may grow from permanent pulps; small canines are present in both jaws; and each jaw carries two long scalpriform incisors, resembling those of Rodents in form and in growing from persistent pulps. The feet are plantigrade and pentadactyle, and the digits were apparently unguiculate. The femur has a third trochanter, and the radius and ulna and tibia and fibula are distinct bones.*

The order includes two distinct families,—one, the *Tillotheridæ*, having molar teeth with distinct roots; whilst the other, *Stylinodontidæ*, possessed rootless molars, which grew from persistent pulps. All the known forms of the order are from the Eocene Tertiary, and the typical species seem to have been from one-half to two-thirds of the size of the Tapir.

The type-genus of the order is *Tillotherium*, which presents a remarkable combination of the characters of the *Ungulata*, *Rodentia*, and *Carnivora*. The general form of the skeleton most closely resembles that of the Carnivores, the skull being like that of the Bears in many respects, whilst the feet are five-toed, with the whole sole applied to the ground, and having ungual phalanges similar to those of the *Ursidæ*. The brain-cavity is of small size, and the cerebral hemispheres did not extend over the cerebellum or the olfactory lobes. The orbits are not complete, but open into the temporal fossæ. The præmolars and molars have grinding crowns, the canines are of small size, and the præmaxillæ carried a pair of large scalpriform incisors (fig. 414), which resemble those of the Rodents in having chisel-shaped crowns, and in growing throughout the life of the animal. As in Rodents, there is a corresponding pair of scalpriform incisors in the lower jaw. The dental formula is—

$$i\,\frac{1-1}{1-1};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{3-3}{2-2};\quad m\,\frac{3-3}{3-3}=30.$$

ORDER IX. TOXODONTIA.—This order includes certain large extinct Mammals from the later Tertiary deposits of South America, the true systematic position of which is still very doubtful; since they present affinities to the *Ungulata*, the Rodents, and the Edentates. The skull is massive and the dentition is very peculiar. The molars and præmolars are bent so as to be strongly convex outwards and concave inwards, with flat grinding-surfaces (fig. 415), and presenting the peculiarity that they are rootless and grow from persistent pulps. Canines are present in the lower jaw; but are of very small

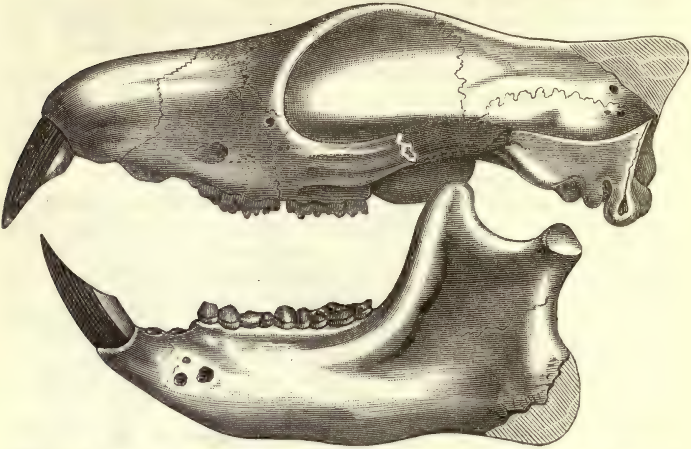

Fig. 414.—*Tillodontia*. Side-view of the skull of *Tillotherium fodiens*, with the lower jaw displaced downwards, one-fourth of the natural size. (After Marsh.)

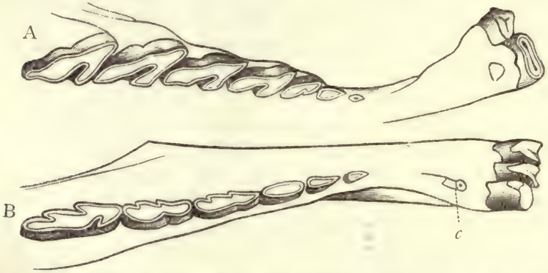

Fig. 415 —A, Right upper jaw of *Toxodon Burmeisteri*, and (B) left lower jaw of the same; *c* Lower canine. (After Burmeister.) Greatly reduced in size.

size (fig. 415, *c*) and are placed in the interval between the incisors and præmolars. In the upper jaw only the sockets for the canines are left. There are four upper and six lower incisors, which are separated by a wide diastema from the præmolars. The dental formula is—

$$i\,\frac{2-2}{3-3};\ c\,\frac{0-0}{1-1};\ pm\,\frac{4-4}{3-3};\ m\,\frac{3-3}{3-3} = 38.$$

There is no third trochanter to the femur, but the structure of the manus and pes is quite unknown.

The only known genera are *Toxodon* and *Nesodon*.

CHAPTER LXXIV.

HYRACOIDEA AND PROBOSCIDEA.

ORDER X. HYRACOIDEA.—This is a very small order which has been constituted by Huxley for the reception of two or three little animals, which make up the single genus *Hyrax*. These have been usually placed in the immediate neighbourhood of the Rhinoceros, to which they have some decided affinities, and they are still retained by Owen in the section of the Perissodactyle Ungulates.

The order is distinguished by the following characters: *There are no canine teeth, and the incisors of the upper jaw are long and curved, and grow from permanent pulps, as they do in the Rodents* (*such as the Beaver*, *Rat*, &c.) *The lower incisors are directed forwards. The molar teeth are singularly like those of the Rhinoceros.* According to Huxley, the dental formula of the aged animal is—

$$i\,\frac{2-2}{2-2};\ c\,\frac{0-0}{0-0};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3} = 36.$$

The fore-feet are tetradactylous, the hind-feet tridactylous, and all the toes have rounded hoof-like nails, with the exception of the inner toes of the hind-feet, which have an obliquely-curved nail. There are no clavicles. The nose and ears are short, and the tail is represented by a mere tubercle. *The placenta is deciduate and zonary, whereas in the Ungulates it is non-deciduate.*

Several species of *Hyrax* are known, but they resemble one another in all essential particulars, and, with the exception of

H. Syriacus, they are exclusively confined to Africa. They are all gregarious little animals, living in holes of the rocks, and capable of domestication. Some forms (*Dendrohyrax*) are arboreal in their habits. The "coney" of Scripture is believed to be the *Hyrax Syriacus*, which occurs in the rocky parts of Syria and Palestine. Another species—the *Hyrax Capensis*, or "Klipdas" ("badger of the cliffs")—occurs commonly in South Africa, and is known by the colonists as the "badger."

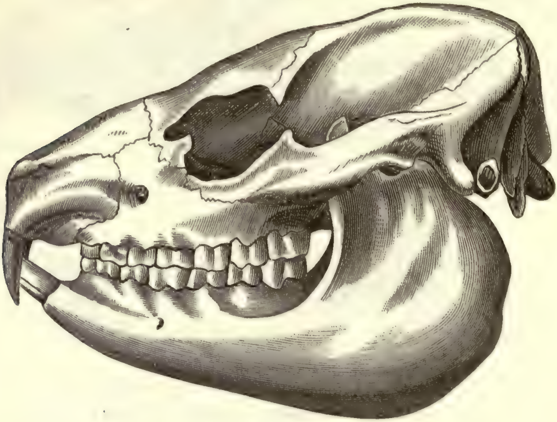

Fig. 416.—Skull of *Hyrax*. (After Cuvier.)

No fossil remains have as yet been discovered which can with certainty be referred to this order.

ORDER XI. PROBOSCIDEA.—The eleventh order of Mammals is that of the *Proboscidea*, comprising no other living animals except the Elephants, but including also the extinct *Mastodon* and *Deinotherium*.

The order is characterised by *the total absence of canine teeth; the molar teeth are few in number, large, and transversely ridged or tuberculate; incisors are always present, and grow from persistent pulps, constituting long tusks* (fig. 417). *In living Elephants there are two of these tusk-like incisors in the upper jaw, and the lower jaw is without incisor teeth.* In the *Deinotherium* this is reversed, there being two tusk-like lower incisors and no upper incisors. In the Mastodons, the incisors are usually developed in the upper jaw, and form tusks, as in the Elephants, but sometimes there are both upper and lower incisors, and both are tusk-like. *The nose is prolonged into a cylindrical trunk, movable in every direction, highly sensitive, and terminating in a finger-like prehensile lobe* (fig. 417). *The nostrils are placed at the extremity of the proboscis. The feet are furnished with five toes each* (fig. 419), but some of those toes may not be provided with hoofs. The feet are furnished with a thick pad of integument, forming the palms of the hands and the soles of the feet. There are no clavicles. The testes are abdominal throughout life. There are two teats, and these are placed upon the chest. *The placenta is deciduate and zonary.*

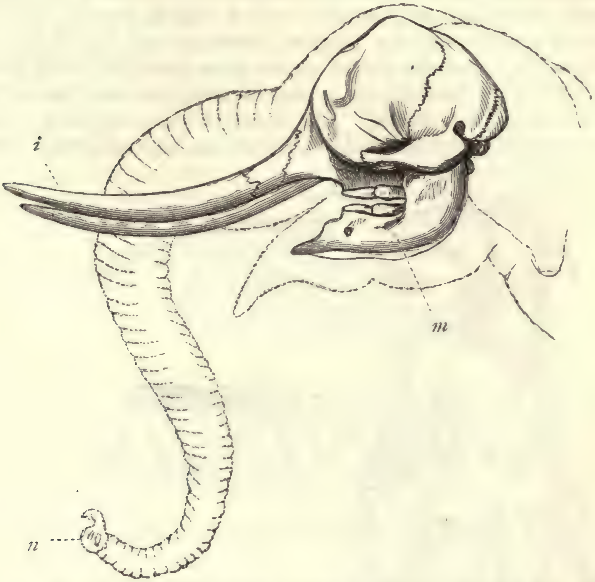

Fig. 417.—Skull of the Indian Elephant (*Elephas Indicus*): *i* Tusk-like upper incisors; *m* Lower jaw, with molars, but without incisors; *n* Nostrils, placed at the end of the proboscis. (After Owen.)

The recent Elephants are exclusively confined to the tropical regions of the Old World, in the forests of which they live in herds. Only two living species are known—the Asiatic Elephant (*Elephas Indicus*) and the African Elephant (*E. Africanus*). There can be no doubt, however, but that the Mammoth (*Elephas primigenius*) existed in Europe within the human period.

In both the living Elephants the "tusks" are formed by an enormous development of the two upper incisors. The milk-tusks are shed early, and never attain any very great size. The permanent tusks grow throughout the life of the animal, and often reach six or seven feet in length, and from fifty to seventy pounds in weight, or even up to one hundred and fifty pounds in aged males. In the Indian Elephant, and its variety the Ceylon Elephant, the males alone have well-developed tusks, but both sexes have tusks in the African species, those of the males being the largest. The lower incisors are absent, and there are no other teeth in the jaws except the large molars, which are of very large size, and are composed of transverse plates of enamel, surrounding tracts of dentine, and bound together by cement. As the tooth wears down, the enamel plates come to project, enclosing islands of dentine, which are narrow and elongated in the Indian Elephant (fig. 418, A), but are lozenge-shaped in the African Elephant (fig. 418, B). In reality, there are six molars on each side of each jaw, but owing to their large size, and the manner in which they succeed each other, there is never more than one (or part of two) in use on each side of each jaw at one time. The first three teeth of the grinder-series, which would ordinarily be supposed to be præmolars, are in reality true molars, as they have no predecessors or successors. None of the molars, in fact, undergo vertical displacement, but the whole series gradually moves forward in the jaw, and the place of each tooth as it slowly advances is taken by the tooth next behind it in the series, each succeeding tooth being usually larger than its predecessor, and having more numerous plates of enamel.

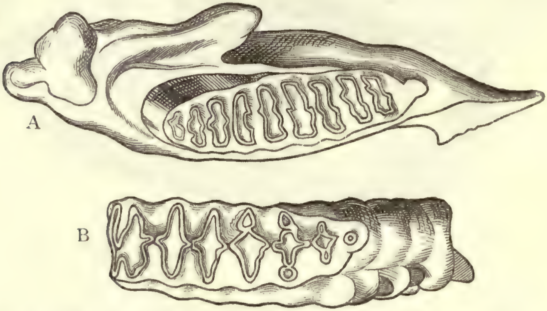

Fig. 418.—A, Left ramus of lower jaw of *Elephas Indicus*, viewed from above (after Cuvier). B, Grinding-surface of molar tooth of *Elephas Africanus* (after Giebel).

The Indian Elephant is the only species which is now caught and domesticated, and as it rarely breeds in captivity, the demand for it is supplied almost entirely by the capture of adult wild individuals, which are taken chiefly by the assistance of those which have been already tamed. The Indian Elephant is distinguished by its concave forehead, its small ears, and the characters of the molars. Its skull is pyramidal, and it has five hoofs on the fore-feet, and only four on the hind-feet. Its colour is generally pale brown. (The so-called "White Elephants" are merely albinos.) The African Elephant, on the other hand, has a strongly convex forehead and great flapping ears. Its colour is darker, its skull is rounded, and it has four hoofs on the fore-feet, and only three on the hind-feet. The African Elephant is chiefly hunted for the sake of its ivory, and there is too much reason to believe that the pursuit will ultimately end in the destruction of these fine animals. A great deal, however, of the ivory of commerce comes from Siberia, and is really derived from the tusks of the now extinct Mammoth, which formerly inhabited the north of Asia in great numbers.

The Elephants are all phytophagous, living entirely on the foliage of shrubs and trees, and other vegetable matters, which they strip off by means of the prehensile trunk. As the tusks prevent the animal from drinking in the ordinary manner, the water is sucked up by the trunk, which is then inserted into the mouth, into which it empties its contents.

Closely allied to the true Elephants are the *Mastodons*, characterised by the fact that the crowns of the molar teeth have nipple-shaped tubercles placed in pairs (fig. 420). Generally speaking, the two upper incisors formed long curved tusks, as in the Elephants, but in some cases there were two lower incisors as well. The various species of *Mastodon* all belong to the later Tertiary and Post-tertiary periods.

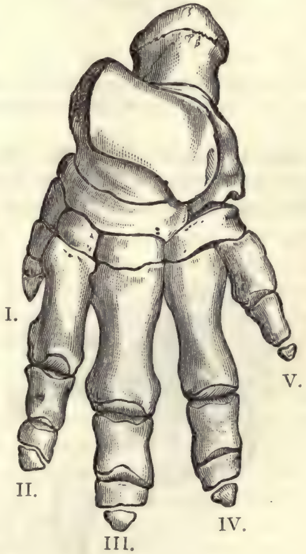

Fig 419.—Hind-foot of the Indian Elephant (*Elephas Indicus*). (After Cuvier.)

The last of the *Proboscidea* is a remarkable extinct animal, the *Deinotherium*. This extraordinary animal has hitherto only been found in Miocene deposits, and little is known of it except its enormous skull. Molars and præmolars were present in each jaw, and the upper jaw was destitute of canines and incisors. In the lower jaw were two very large tusk-like incisors, which were not directed forwards as in the true Elephants, but were bent abruptly downwards (fig. 421). The animal must have attained an enormous size, and it is probable

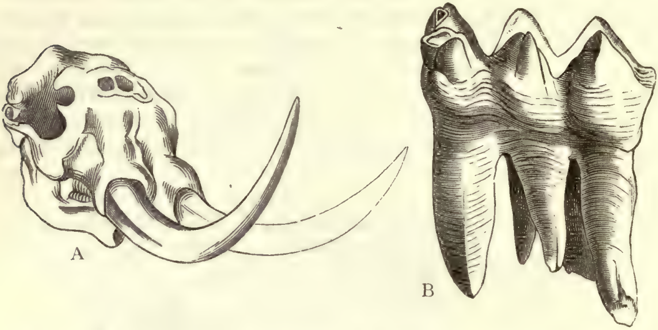

Fig. 420.—A, Skull of *Mastodon giganteum;* B, Side-view of the second true molar of *Mastodon giganteum*. (After Owen.)

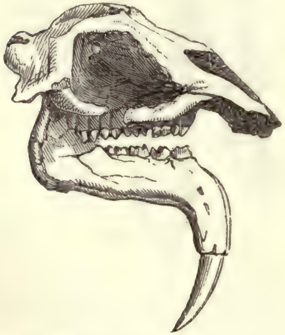

Fig. 421.— Skull of *Deinotherium giganteum*. Miocene Tertiary.

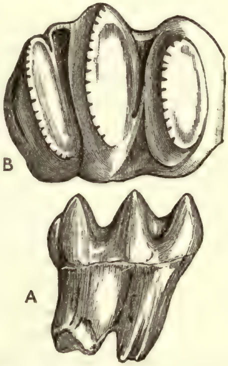

Fig. 422.—A, Side-view of the third molar of *Deinotherium giganteum;* B, Grinding surface of the same. Miocene Tertiary. (After Kaup.)

that the curved tusks were used either in digging up roots, or in mooring the animal to the banks of rivers, for it was probably aquatic or semi-aquatic in its habits. The whole of the præmolars and molars were in use at one time, and their crowns are crossed by strong transverse ridges, which give them a marked Tapiroid character, while in some respects they resemble the teeth of the Mastodons. It is placed by De Blainville in the *Sirenia*, being regarded as a Dugong with tusk-like lower incisors; but this view has been rendered untenable by the discovery of limb-bones of a distinctly Proboscidean type.

As regards the *distribution* of the *Proboscidea* in *time*, the order came into existence in the Miocene period, where it is represented by all its three sections, *Deinotherium*, *Mastodon*, and *Elephas*.

The genus *Deinotherium*, as just mentioned, is exclusively confined to the Miocene period.

The genus *Mastodon* is characteristic in Europe of the Miocene and Pliocene; but in North America it is represented in the Post-pliocene, and it occurs also in deposits of the same age in South America.

No Elephant has yet been discovered in the Miocene rocks of Europe, but six species are known from Miocene (Pliocene?) strata in India. In the Pliocene period Europe possessed its Elephants (viz., *E. priscus* and *E. meridionalis*); but the best known of the extinct Elephants, as well as the most modern, is the Mammoth (*E. primigenius*). This enormous animal is now wholly extinct, but it formerly abounded in the northern parts of Asia and over the whole of Europe. It occurred also in Britain, and unquestionably existed in the earlier portion of the human period, its remains having been found in a great number of instances in connection with human implements. From its great abundance in Siberia, it might have been safely inferred that the Mammoth was able to endure a much colder climate than either of the living elephants. This inference, however, has been rendered a certainty by the discovery of the body of more than one Mammoth embedded in the frozen soil of Siberia. These specimens had been so perfectly preserved that even microscopical sections of some of the tissues could be made; and in one case even the eyes were preserved. From these specimens we know that the body of the Mammoth was covered with long woolly hair.

CHAPTER LXXV.

CARNIVORA.

ORDER XII. CARNIVORA.—The twelfth order of Mammals is that of the *Carnivora*, comprising the *Feræ*, or Beasts of Prey, along with the old order of the *Pinnipedia*, or Seals and Walruses, these latter being now almost universally regarded as merely a group of the *Carnivora* modified to lead an aquatic life.

The *Carnivora* are distinguished by always possessing *two sets of teeth, which are simply covered by enamel, and are always of three kinds—incisors, canines, and molars—differing from one another in shape and size. The incisors are generally* $\frac{3-3}{3-3}$ (*except in some seals*)*; the canines are always* $\frac{1-1}{1-1}$, *and are invariably much larger and longer than the incisors. The præmolars and molars are mostly furnished with cutting or trenchant edges; but they graduate from a cutting to a tuberculate form, as the diet is strictly carnivorous, or becomes more or less miscellaneous.*

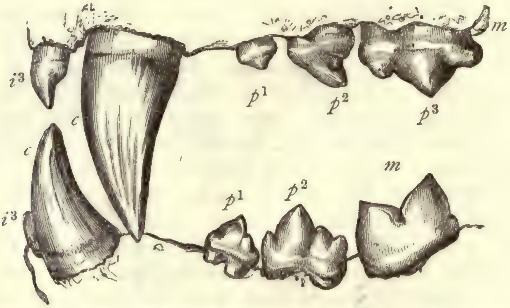

Fig. 423.—Permanent dentitition of the Lion (*Felis leo*). In the upper jaw the letter p^3 indicates the upper carnassial, while in the lower jaw the letter m indicates the lower carnassial.

In the typical and most highly specialised Carnivores (such as the *Felidæ*), the last præmolar in the upper jaw, and the first molar in the lower jaw (fig. 423, pm^3 and m) are specially developed, and are known as the "carnassial" teeth, having a sharp cutting-edge; whereas in other cases the corresponding teeth are blunt and "tuberculated." Even in their most trenchant condition, the carnassial tooth commonly has a more or less developed tuberculated process or heel, on the inside of its cutting-edge. In various Carnivores a number, or all, of the præmolars and molars may be "tuberculate," their crowns being adapted for bruising rather than cutting. As a general rule, the shorter the jaw, and the fewer the præmolars and molars, the more carnivorous is the animal. The jaws are so articulated as to admit of vertical but not of horizontal movements; the zygomatic arches are greatly developed to give room for the powerful muscles of the jaws; and the orbits are not separated from the temporal fossæ. The intestine is comparatively short.

In all the *Carnivora the clavicles are either altogether wanting, or are quite rudimentary. The toes are provided with sharp curved claws. The teats are abdominal; and the placenta is deciduate and zonular.*

The order *Carnivora* is divided into three very natural sections:—

Section I. Pinnigrada or *Pinnipedia.*—This section comprises the Seals and Walruses, in which the fore and hind limbs are short, and are expanded into broad webbed swimming-paddles (fig. 424, B). The hind-feet are placed very far back, nearly in a line with the axis of the body, and they are more or less tied down to the tail by the integuments.

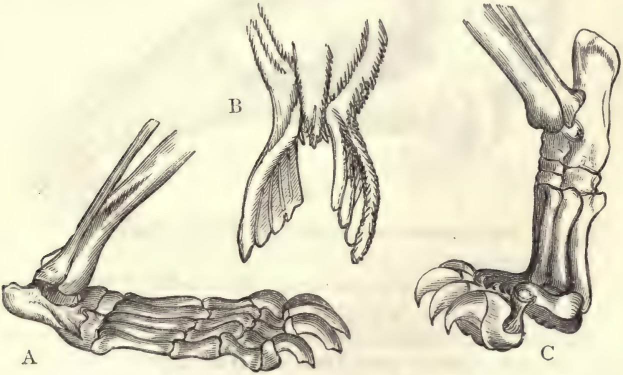

Fig. 424.—Foot of *Carnivora* (after Owen). A, *Plantigrada*, Foot of Bear; B, *Pinnigrada*, Hind-feet of Seal; C, *Digitigrada*, Foot of Lion.

Section II. Plantigrada.—This section comprises the Bears, and their allies, in which the whole, or nearly the whole, of the foot is applied to the ground, so that the animal walks upon the *soles* of the feet (fig. 424, A).

Section III. Digitigrada.—This section comprises the Lions, Tigers, Cats, Dogs, &c., in which the heel of the foot is raised entirely off the ground, and the animal walks upon the tips of the toes (fig. 424, C).

SECTION I. PINNIGRADA OR PINNIPEDIA.—This section of the *Carnivora* comprises the amphibious Seals and Walruses, which differ from the typical Carnivores merely in points connected with their semi-aquatic mode of life. The body in these forms is elongated and somewhat fish-like in shape, covered with a short dense fur or harsh hairs, and terminated behind by a short conical tail. All the four limbs are present, but are very short, and the five toes of each foot are united together by the skin, so that the feet form powerful swimming-paddles. The hind-feet are of large size, and are placed far back, their axis nearly coinciding with that of the body (figs. 424, 425). From this circumstance, and from the fact that the integument often extends between the hind-legs and the sides of the short tail, the hinder end of the body forms an admirable swimming apparatus, similar in its action to the horizontal tail-fin of the *Cetacea* and *Sirenia.* The tips of the toes are furnished with claws, but the powers of terrestrial locomotion are very limited. On land, in fact, the typical Seals can only drag themselves along laboriously, chiefly by the contractions of the abdominal muscles. On the other hand, the Eared Seals (*Otariadæ*) can use their hind-limbs freely upon the land. The ears are of small size, and are mostly only indicated by

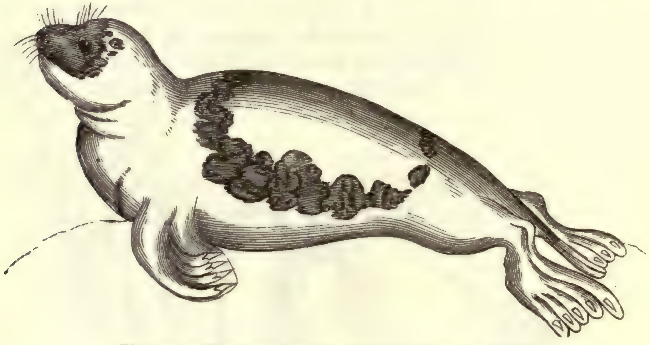

Fig. 425.—The Greenland Seal (*Phoca Grœnlandica*).

small apertures, which the animal has the power of closing when under water. The bones are light and spongy, and beneath the skin is a layer of fat or blubber. The dentition (fig. 426) varies, but teeth of three kinds are always present, in the young animal at any rate. The canines are always long and pointed, and the molars are generally furnished with sharp cutting-edges. The lower incisors may be reduced to four or to two in number, or may even be wanting (Walrus); and the upper incisors may fall below the normal six. The dental formula of the common Seal (fig. 426) is—

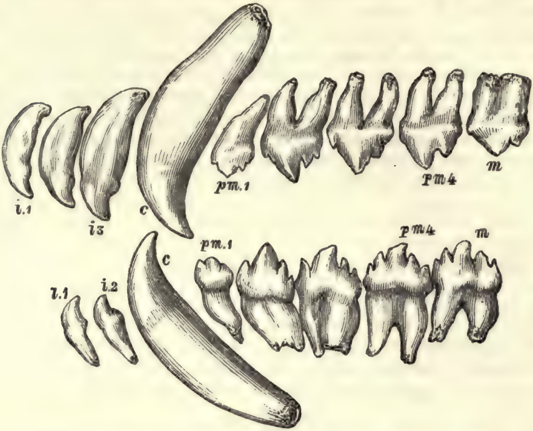

Fig. 426.—Dentition of the common Seal (*Phoca vitulina*).

$$i\,\frac{3-3}{2-2};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{4-4};\quad m\,\frac{1-1}{1-1}=34.$$

The section *Pinnigrada* includes the three families of the Earless Seals (*Phocidæ*), the Eared Seals (*Otariadæ*), and the Walruses (*Trichecidæ*).

The typical Seals (*Phocidæ*) are distinguished from the Walruses by the presence of incisor teeth in both jaws, and by canines of moderate size; while the absence of ears and the inability to use the hind-limbs on land separate them from the *Otariadæ*. They form a very numerous family, of which species are found in almost every sea out of the limits of the tropics. They abound, however, especially in the seas of the Arctic and Antarctic regions. They live for the most part upon fish, and when awake, spend the greater part of their time in the water, only coming on land to bask and sleep in the sun and to suckle their young. They appear to be universally polygamous. The body is covered with a short fur, interspersed with long bristly hairs; and the lips are furnished with long whiskers, which act as organs of touch. The seals are very largely captured for the sake of their blubber and skins.

The only common British seal is the *Phoca vitulina*, which occurs not uncommonly on the northern shores of Scotland, and ranges over almost the whole of the shores washed by the North Atlantic and the seas of Greenland. It is yellowish-grey in colour, and measures from three to five feet in length. Other seals attain a much greater length—the Great Seal measuring from eight to ten feet, and the Elephant Seal (*Macrorhinus*) of the South Pacific, reaching a length of twenty feet.

The Eared Seals or Sea-lions (*Otariadæ*) differ from the typical Seals in the possession of small conical ears, and in the much greater freedom of the limbs, enabling the animal to walk with comparative ease on land. The Eared Seals are principally found on the shores of the continents and islands washed by the Pacific; but they are also found in the extreme southern part of the Atlantic as far northwards as the mouth of the Rio Plata.

The third family of the Pinnigrade Carnivores is that of the *Trichecidæ*, comprising only the Walrus or Morse (*Trichecus rosmarus*). The chief peculiarity by which the Walrus is distinguished from the true Seals is found in the dentition. According to Owen, there are six incisors in the upper jaw and four in the lower; but these are only present in the young animal, and soon disappear, with the exception of the outermost pair of upper incisors. The upper canines are enormously developed, growing from persistent pulps, and constituting two large pointed tusks, which attain a length of over fifteen inches (fig. 427). The direction of the tusks is downwards and slightly outwards, and they project considerably below the chin. The upper jaw has three præmolars and two molars, with flattened crowns, on each side, and the lower jaw has the same

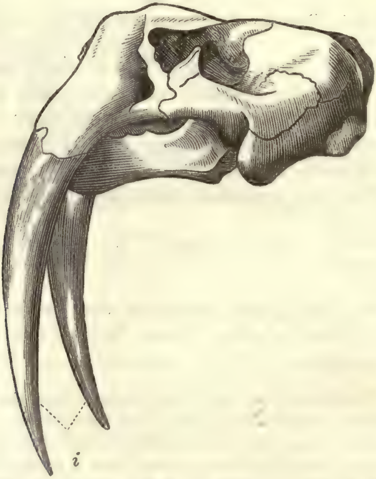

Fig. 427.—Skull of the Walrus (*Trichecus rosmarus*), after Owen. *i* Tusk-like upper canines.

number of præmolars and a single molar on each side; but the true molars are caducous, so that the dental formula of the adult animal is—

$$i\,\frac{1-1}{0-0};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{0-0}{0-0} = 18.$$

Except as regards its dentition, the Walrus agrees in all essential respects with the Seals. It is a large and heavy animal, attaining a length of from ten to fifteen feet or upwards. The body is covered with short brownish or yellowish hair, and the face bears many long stiff bristles. There are no external ears. The chief use of the tusk-like canines appears to be that of assisting the unwieldy animal to get out of the water upon the ice; but they doubtless serve as weapons of offence and defence as well, and they are used for digging up burrowing shell-fish out of the sand. The Walrus is hunted by whalers, both for its blubber, which yields an excellent oil, and for the ivory of the tusks. It is found, living in herds, in the Arctic seas, being especially abundant at Spitzbergen and Nova Zembla.

SECTION II. PLANTIGRADA (ARCTOIDEA).—The Carnivorous animals belonging to this section apply the whole or the greater part of the sole of the foot to the ground (fig. 424, A); and the portion of the sole so employed is destitute of hairs in most instances (the sole is hairy in the Polar Bear). From the structure of the foot, the *Plantigrada* have great power of rearing themselves up on the hind-feet. They approach the *Insectivora* in their comparatively slow movements and their nocturnal habits, and in possessing no cæcum. They mostly hibernate, and their feet are always pentadactylous.

The typical family of the Plantigrade *Carnivora* is that of the *Ursidæ* or Bears, in which the entire sole of the foot is applied to the ground in walking. The *Ursidæ* are much less purely carnivorous than the majority of the order, and, in accordance with their omnivorous habits, the teeth do not exhibit the typical carnivorous characters. The incisors and canines have the ordinary carnivorous form, but the "carnassial" teeth have tuberculate crowns, instead of a sharp cutting-edge. The dental formula in *Ursus* (fig. 428) is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{2-2}{3-3} = 42.$$

The dental formula of the Bears is thus the same as that of the Dogs; but the second and third præmolars are small and usually deciduous; while the first præmolar is also often caducous. The last præmolar and all the molars have tuberculate crowns, and the carnassials are not of specially large size, these characters being equally present in the flesh-eating Polar Bear and the strictly vegetarian Sun-bear.

The claws are formed for digging, large, strong, and curved, but are not retractile. The tongue is smooth; the ears small, erect, and rounded; the tail short; the nose forms a movable truncated snout; and the pupil is circular.

As shown by their smooth tongues and tuberculate molars, the Bears are not peculiarly or strictly carnivorous. They eat flesh when they can obtain it, but a great part of their food is of a vegetable nature.

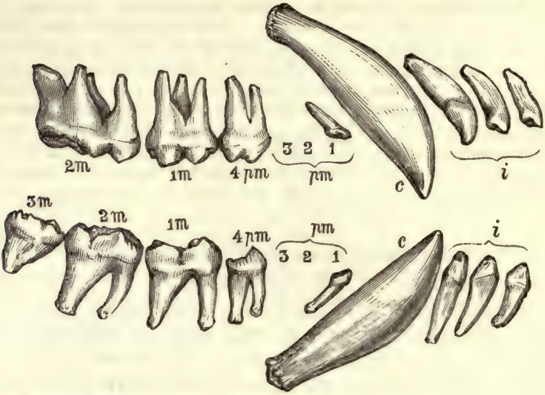

Fig. 428.—Dentition of the Polar Bear (*Thalassarctos maritimus*).

The Bears are very generally distributed over the globe, Australia and Africa alone having no representative of the family. The common Brown Bear (*Ursus arctos*) was at one time an inhabitant of Britain, and also existed over the whole of Europe. At the present day the Brown Bear is only found in the great forests of the north of Europe and in Asia, and in the Arctic portions of North America. It feeds on roots, fruits, honey, insects, and, when it can obtain them, upon other Mammals. It attains a great age, and hibernates during the winter months. Very nearly allied to the Brown Bear is the Black Bear of America (*Ursus Americanus*). Both are of some commercial value, being hunted for the sake of their skins, fat, and tongues. A much larger American species is the Grizzly Bear (*Ursus ferox*), found in many parts of the American continent. It is about twice as large as the ordinary Bear, but it is said to subsist to a great extent upon vegetable food, such as acorns. The most remarkable, however, of the Bears is the great White Bear (*Thalassarctos maritimus*), which is exclusively a native of the Arctic regions. It is a very large and powerful animal, the fur of which is cream-coloured. The paws are very long, and the soles of the feet are covered with coarse hair, giving the animal a firm foothold upon the ice. The Polar Bear differs from the other *Ursidæ* in being exclusively carnivorous, since vegetable food would be generally unattainable. It is as much at home in the water as on land, and lives chiefly upon seals and fish, and the carcasses of Cetaceans.

Amongst the other Bears may be mentioned the Sun-bears (*Helarctos*) of the Malayan Archipelago, the Honey-bears (*Prochilus* or *Melursus*) of India, and the Spectacled Bear (*Helarctos* or *Tremarctos ornatus*) of the

Peruvian and Chilian Andes, the sole representative of the *Ursidæ* in South America.

The family *Procyonidæ* includes a number of small American Carnivores, which are nearly allied to the Bears. The Racoons (*Procyon*, fig. 429) are natives of tropical and northern America, and have a decided external resemblance to the Bears. They have tolerably long tails, however, and sharp muzzles. The commonest species is the *Procyon lotor* of North America, which derives its specific name from its habit of soaking its food in water before eating it. The dental formula of *Procyon* is—

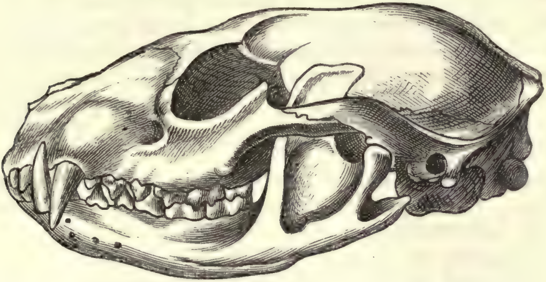

Fig. 429.—Skull of Racoon (*Procyon lotor*). (After Giebel.)

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{2-2}{2-2}=40.$$

The Coatis (*Nasua*) are very closely allied to the Racoons, and are exclusively confined to the American continent. The Kinkajous (*Cercoleptes*) are inhabitants of South America, extending their range northwards to Mexico, and, as is the case with so many of the animals of this continent, they are adapted for an arboreal life, to which end their tails are prehensile. They appear to represent in the western hemisphere the Lemurs of the Old World, to which they present certain points of affinity. Forming a transition between the *Procyonidæ* and the Civets (*Viverridæ*) is the curious Cacomixle (*Bassaris astuta*), which is a native of California, Texas, and parts of Mexico, and is arboreal in its habits.

Nearly related to the preceding is the family of the *Æluridæ*, comprising the well-known "Wah" or "Panda" (*Ælurus fulgens*) of India and Thibet, and the *Æluropus* of the latter country. The former is a cat-like animal, chestnut-brown above and black inferiorly, with a white face and ears, and the latter is almost completely white in colour. Like the Kinkajous, but unlike the Coatis and Racoons, the *Ælurus* has retractile claws.

The only remaining family of the *Plantigrada* is that of the *Melidæ* or Badgers, characterised by their elongated bodies and short legs, and forming a transition between the *Ursidæ* and *Mustelidæ*. They agree with the latter group in the possession of odoriferous anal glands. The dental formula of the Badger is as follows (Baird)—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3\ (4-4)};\ m\,\frac{1-1}{2-2}=34\ (36).$$

The first præmolar in the lower jaw is very minute, and is soon lost; the upper carnassial has a well-marked internal tubercle; and the upper molar is of comparatively large size, nearly equalling the carnassial in its dimensions.

The common Badger (*Meles taxus*), which may be regarded as the type of this group, occurs in Britain, and is one of the most inoffensive of animals. It is nocturnal in its habits, and is a very miscellaneous feeder, not refusing anything edible which may come in its way, though living mainly on roots and fruits. The Badger burrows with great ease, and can bite very severely. The European Badger is represented in the United States and Canada by the "Siffleur" (*Taxidea Labradorica*), and in the hilly parts of India by the Indian Badger (*Meles* or *Arctonyx collaris*). The Glutton (*Gulo luscus*), often called the Wolverine, is of common occurrence in the northern parts of Europe, Asia, and America. It is from two to three feet in length, and though doubtless a tolerably voracious animal, it is certainly not so much so as to deserve the name of Glutton. The Grison (*Galictis*) is a closely-allied form which is found in South America. These two genera are often placed among the *Mustelidæ*. The Ratels or Honey-badgers (*Mellivora*) are much like the common Badger in their habits and appearance, but they have only one lower molar (the carnassial) on each side. They are natives of southern and eastern Africa, and India. The Skunks (*Mephitis*) are sometimes placed in this family, to which they are allied through the singular *Mydaus* of Java and Sumatra.

SECTION III. DIGITIGRADA.—In this section of the *Carnivora* the heel is raised above the ground, with the whole or the greater part of the metacarpus and metatarsus, so that the animals walk more or less completely on the tips of the toes (fig. 424, C). No absolute line, however, of demarcation can be drawn between the Plantigrade and Digitigrade sections of the *Carnivora*, since many forms (*e.g.*, *Mustelidæ* and *Viverridæ*) exhibit transitional characters, and it has even been proposed to place these in a separate section, under the name of *Semi-plantigrada*. Moreover, the *Mustelidæ* and *Melidæ* are so nearly allied that they can with difficulty be kept apart.

The first family of the *Digitigrada* is that of the *Mustelidæ* or Weasels, including a number of small Carnivores, with short legs, elongated worm-like bodies, and a peculiar gliding mode of progression (hence the name of *Vermiformes*, sometimes applied to the group). The dental formula of *Mustela* proper is—

$$i\,\frac{3-3}{3-3};\; c\,\frac{1-1}{1-1};\; pm\,\frac{4-4}{4-4};\; m\,\frac{1-1}{2-2} = 38.$$

In the nearly-allied genus *Putorius* (fig. 430) there is a præmolar less above and below.

Among the best known of the *Mustelidæ* are the common Weasel (*Putorius vulgaris*), the Polecat (*Putorius fœtidus*), and the Ferret (*Putorius furo*), the last being usually regarded as an albino variety (now permanent) of one of the Polecats. It is really an African form, but it has been long domesticated in Europe. Nearly-allied types are the Ermine or Stoat (*Putorius erminea*), and the Minks (*P. vison* and *P. lutreola*) of North America and Europe. Among the species of *Mustela* proper may be mentioned the Pine-marten (*M. martes*) and Stone-marten (*M. foina*) of Europe and Asia, the Pekan or "Fisher" (*M. Pennantii*) of North America, the true Sable (*M. zibellina*) of northern Asia, and the American Sable (*M. Americana*). The *Mustelidæ* are of commercial importance as yielding beautiful and highly-valued furs, the skins of the

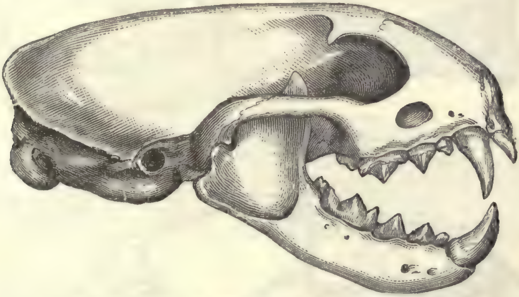

Fig. 430.—Skull of the Polecat (*Putorius fœtidus*).

Sable, Ermine, Black Mink, and Pekan, being specially sought after.

Almost all the Weasels have a very disagreeable odour, produced by the secretion of greatly-developed and modified sebaceous glands, placed in the neighbourhood of the anus, and known as the anal glands. In this respect, however, the nearly-allied genus *Mephitis*, comprising the American Skunk, is *facile princeps*. The Skunk is a pretty little animal, with a long bushy tail, and when unmolested it is perfectly harmless. If pursued or irritated, however, it has the power of ejecting the secretion of the anal glands to a greater or less distance with considerable force. The odour of this secretion is so powerful and persistent that no amount of washing will remove it from a garment, and its characters are said to be of the most intensely disagreeable description.

Nearly related to the family of the *Mustelidæ* are the Otters (*Lutra*), distinguished by the possession of webbed feet adapted for swimming. The body is long, the legs short, and the tail long, stout, and horizontally flattened. The common Otter (*Lutra vulgaris*, figs. 431, 432) is a native of Britain, frequent-

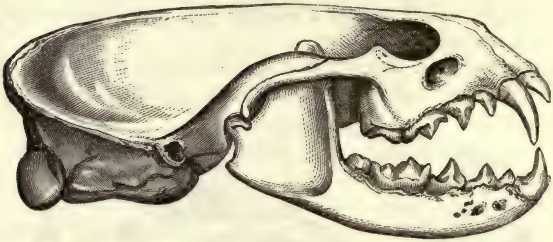

Fig. 431.—Skull of common Otter (*Lutra vulgaris*), viewed from one side. (After Coues.)

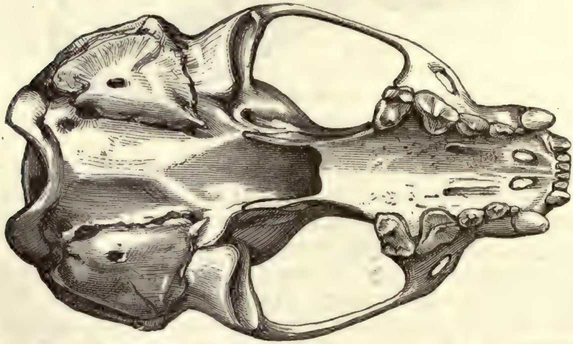

Fig. 432.—Under view of the skull of the common Otter. (After Coues.)

ing the banks of streams and lakes. It lives upon fish, and is highly destructive to salmon. A closely-allied form is the American Otter (*Lutra Canadensis*). In the Sea-otters (*Enhydris*) the tail is very short. They are found on both sides of the North Pacific, and yield a very valuable fur, being much more strictly aquatic in their habits than the ordinary Otters. Besides *Enhydris*, a species of Sea-otter belonging to the genus *Nutria* is found on the shores of North and South America, ranging from California to Chili.

The second family of the Semi-plantigrade Carnivores is that of the *Viverridæ*, the Civets and Genettes. They are all of moderate size, with sharp muzzles and long tails, and more or less striped, or banded, or spotted. The dental formula of *Viverra* is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{2-2}{2-2} = 40.$$

The upper carnassial (the 4th præmolar) and the lower carnassial (the 1st molar) have cutting edges (fig. 433); while both the upper molars and the last lower molar have tuberculate crowns. The canines are long, sharp, and pointed. The tongue is roughened by numerous prickly papillæ. The claws are semi-retractile, and the pupils can contract, on exposure to light, till they resemble a mere line. In most of their charac-

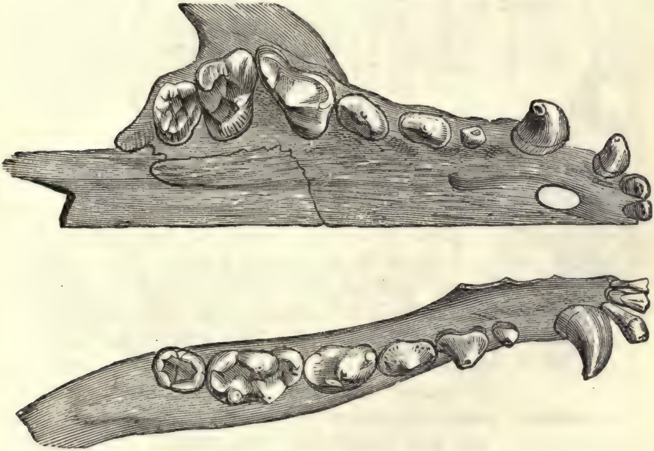

Fig. 433.—Dentition of the Civet-cat (*Viverra civetta*). The upper figure shows the upper jaw, the lower figure gives the lower teeth.

ters, therefore, the Civets are much more highly carnivorous than are any of the preceding families, and they approach in many respects very close to the typical group of the *Digitigrada* (viz., the *Felidæ*), having especially very close affinities with the Hyænas. Many of the species of the family are furnished with anal glands, which secrete the peculiar fatty substance known as "civet." All the *Viverridæ* belong to the Old World.

The true Civet-cat is the *Viverra civetta*, a native of North Africa and Eastern Asia. It is a small nocturnal animal, which climbs trees with facility, and feeds chiefly upon small mammals, reptiles, and birds, but also upon roots and fruits. It furnishes the greater part of the "civet" of commerce, which was formerly in great repute both as a perfume and as a medicinal agent. It is a pomade-like substance, with a strong musky odour, and is secreted by a deep double pouch beneath the anus. The Genette (*Viverra genetta*) is very closely related to the preceding, and is a native of Africa and Southern Europe, being not uncommonly domesticated and kept like a cat. The anal pouch in the Genette is much reduced in size, and has hardly any perceptible secretion. Another nearly-allied form is the Ichneumon (*Herpestes*), one species of which is kept as a domestic animal in Egypt, and lives upon Snakes, Lizards, the eggs of the Crocodile, and small Mammals.

Among the numerous other forms which are referred to the *Viverridæ* may be mentioned the *Paradoxurus* of the Indian province; the prehensile-tailed "Benturongs" (*Arctictis*) of India, and Sumatra and Java; the web-footed *Cynogale* of Borneo; the "Mangue" (*Crossarchus*) of Western Africa; the "Suricate" (*Rhyzæna*) of South Africa; and the curious *Cryptoprocta* of Madagascar.

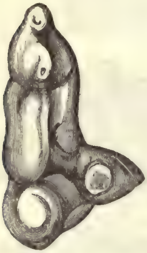

Fig. 434.—Crown of the left upper carnassial of the striped Hyæna (*H. striata*), of the natural size.

Forming a transition between the *Viverridæ* and the *Felidæ* is the family of the *Hyænidæ*, distinguished by the fact that, alone of all the *Carnivora*, both pairs of feet have only four toes each. The hind-legs are shorter than the fore-legs, so that the trunk sinks towards the hind-quarters, and the tail is short. The tongue is rough and prickly. The head is extremely broad, the muzzle rounded, and the muscles of the jaw extremely powerful and well developed. The claws are non-retractile. All the præmolars and molars are trenchant except the last upper molar, which is tuberculate. The upper carnassial has an internal tubercle (fig. 434), and the lower carnassial is wholly trenchant. The dental formula is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{3\ \ 3};\ m\,\frac{1-1}{1-1} = 34.$$

All the known species of Hyæna are confined to the Old World. The striped Hyæna (*H. striata*) is found in North

Africa, Asia Minor, Arabia, and Persia, ranging into India. The spotted Hyæna (*H. crocuta*) occurs all over Africa south of the Sahara; and the Brown Hyæna (*H. brunnea*) is also found in the south of Africa.

Closely allied to the Hyænas is the curious Aardwolf (*Proteles*), of South Africa, sometimes raised to the rank of a distinct family (*Protelidæ*), which has decided affinities with the Civets. It has the fore-feet pentadactylous, and the hind-feet tetradactylous (as in the Dogs). It is a nocturnal burrowing animal, about as large as a Fox, and of a yellowish-grey colour, with black stripes on the sides, and it feeds on White Ants and carrion.

The next family is that of the *Canidæ*, comprising the Dogs, Wolves, Foxes, and Jackals. The members of this family are characterised by having pointed muzzles, smooth tongues, and non-retractile claws. The fore-feet have five toes each, the hind-feet have only four. A large cæcum is present (being small in the Cats and absent in the Bears). The snout is prolonged, and there is a numerous series of teeth (fig. 435), the dental formula of the Dog being—

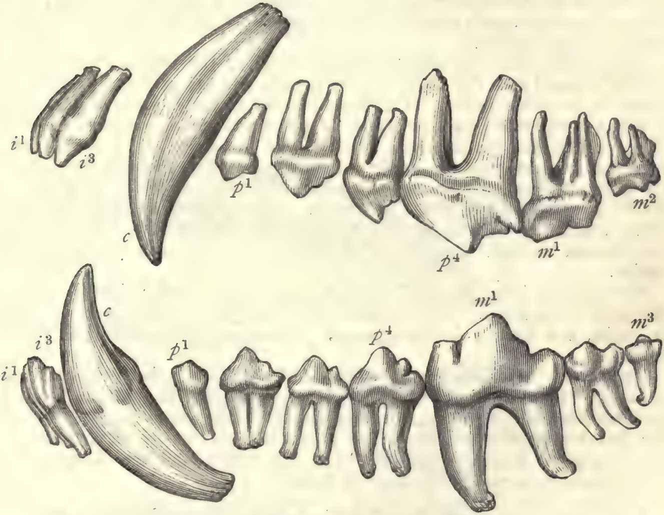

Fig. 435.—Dentition of the Wolf (*Canis lupus*): p^4 Upper carnassial; m^1 Lower carnassial.

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{2-2}{3-3} = 42.$$

Some of the anterior præmolars, and especially the first, may disappear in late life, and the carnassial teeth are of large size. Both of the upper molars and the last two of the lower molars on each side are tuberculate.

The true Dogs (*i.e.*, the Dog and Wolf) have round or oblique pupils, and a tail which is of moderate length and rarely very hairy. The Foxes (*Vulpes*) have very long bushy tails, and the pupil contracts to a mere line.

The Dog (*Canis familiaris*) is only known to us at the present day as a domesticated animal. Such wild dogs as there are, are probably merely derived from the domestic dog; and the original stock, or stocks, from which our numerous varieties of dogs have sprung, is still uncertain. It is worth while remembering, however, that all our varieties of dogs are capable of interbreeding; and there is a strong probability that the Wolf is the parent stock of at least *some* of our domestic breeds. The Dog, in fact, will interbreed with both the Wolf and the Jackal. The "native dog" (*Canis dingo*) of Australia is generally supposed to be only a variety of the *Canis familiaris*, and this is certainly the case with the so-called "native dog" of New Zealand.

The genus *Canis*, besides the Dog, contains the well-known Jackal (*Canis aureus*) and the Wolf (*Canis lupus*), and many writers place the Foxes in the same genus. The Foxes, however, are better considered as forming a separate genus (*Vulpes*), of which there are many species, all more or less like the common Fox (*Vulpes vulgaris*). One of the most remarkable species is the Arctic Fox (*Vulpes lagopus*), which abounds in the Arctic regions, and changes its colour with the season, being brown or bluish in summer, and white in winter. The soles of its feet are hairy. Other well-known Foxes are the Red Fox (*V. fulvus*) of North America, the Deccan Fox (*V. Bengalensis*) of India, and the Caama (*V. Caama*) of Africa.

The Jackals have a round pupil, a long muzzle, and a dental formula like that of the Dogs. They inhabit Asia and Africa, are gregarious, hunt in packs, and burrow in the ground. Other species are found in South America.

One of the most aberrant members of the *Canidæ* is the curious *Lycaon pictus* or "Hunting Dog" of South Africa, which agrees with the Dogs in its dentition and osteology, but resembles the Hyænas in the fact that all the feet are tetradactylous. Other aberrant members of the *Canidæ* are the long-eared *Megalotis Lalandii* of South Africa, and the Racoon-Dog (*Nyctereutes procyonoides*) of Eastern Asia.

The last group of the *Digitigrada* is that of the *Felidæ* or Cat tribe, comprising the most typical members of the whole order of the *Carnivora*, such as the Lions, Tigers, Leopards, Cats, and Panthers. The members of this family all walk upon the tips of their toes, the soles of their feet being hairy, and the whole of the metacarpus and heel being raised above the ground (fig. 424, C). The jaws are short, and owing to this fact, and to the great size of the muscles concerned in mastication, the head assumes a short and rounded form, with an abbreviated and rounded muzzle. The molars and præmolars (fig. 423) are fewer in number than in any other of the *Carnivora* (hence the shortness of the jaws), and they are all trenchant, except the last molar in the upper jaw, which is very small and is tuberculate. The upper carnassial has three lobes, and a blunt heel or internal process. The lower carnassial has two cutting lobes, and no internal process. The dental formula is—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{3-3}{2-2};\quad m\,\frac{1-1}{1-1} = 30.$$

The legs are nearly of equal size, and the hind-feet have only four toes each, whilst the fore-feet have five. All the toes are furnished with strong, curved, retractile claws, which, when not in use, are withdrawn within sheaths by the action of elastic ligaments, so as not to be unnecessarily blunted. The ungual phalanges (fig. 436) are strongly bent near their middle, and the resistance of the ligaments which retract the claws is overcome (when the claws are to be protruded) by the contraction of the *flexor profundus perforans.* The tongue is roughened and rendered prickly by the presence of horny papillæ, thus rendering it a most efficient rasp in licking the flesh from the bones of the prey. All the members of this group are exceedingly light upon their feet, and are excessively muscular, and they have all the habit of seizing their prey by suddenly springing upon it.

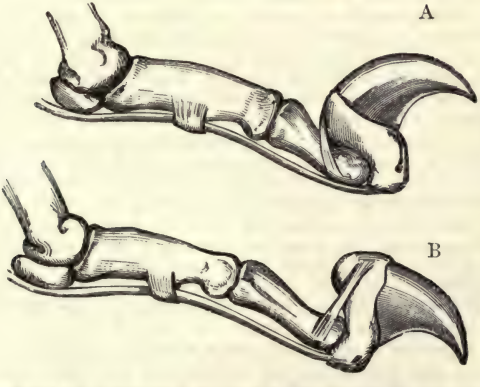

Fig. 436.—Bones and ligaments of the toe of a Cat, showing the claw retracted (A) and protruded (B).

It is questionable if any good genera have hitherto been established in this family, as far as recent forms are concerned, and all the living species may be considered as belonging to the single genus *Felis*. The species of *Felidæ* are found all over the world, except in Australia, New Zealand, the Malayan Archipelago east of "Wallace's line," and the Antilles.

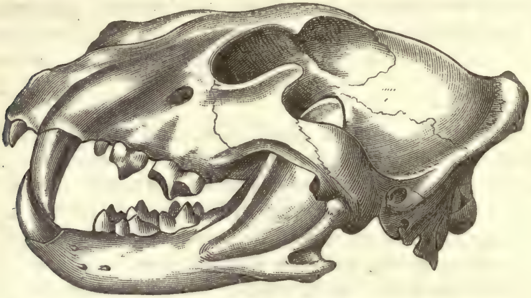

Fig. 437.—Side-view of the skull of the Lion (*Felis leo*).

The Lion (*Felis leo*) is too well known to require much special notice. Its colour is always uniform, generally a yellowish or reddish brown. The tail is terminated by a tuft of long hairs, and the male is usually furnished with a mane, which is very short, however, in an Indian variety. The Lion is exclusively confined to the Old World, and is an inhabitant of Africa and the south-western parts of Asia. It is doubtful how far any valid species of Lions have as yet been established. The Lions are all nocturnal, and capture their prey by suddenly leaping upon it. They are by no means the generous and courageous animals they are generally considered to be; but, on the contrary, are cruel, cunning, and cowardly. They are enormously strong, and it is said that a full-grown Lion can run, and even leap, though carrying an ox in its jaws. Though now much restricted in its range, the Lion had formerly a much more extensive distribution, a form considerably larger than the modern species having formerly existed in Europe, and even in Britain (*Felis spelæa*). High authorities, however, doubt if the "Cave-lion" is specifically separable from the existing *Felis leo*.

In the Tigers (*Felis tigris*), the tail is without a tuft of hairs at its extremity, and the skin is marked with stripes or spots. The Royal or Bengal Tiger is a native of southern Asia, but occurs also in Java, Borneo, and Sumatra. The skin is reddish yellow, marked with numerous transverse black stripes. It is a large and powerful animal, and upon the whole, is probably a more dangerous opponent than even the Lion.

Of the large Spotted Cats, the largest is the Jaguar (*Felis onca*), which inhabits South America and the southern parts of North America. It is a very large and powerful animal, said to be able to carry a bullock without difficulty, and it can both swim and climb with great facility. Another American species is the Puma (*Felis concolor*), in which the colour is uniformly reddish brown. It is exclusively confined to America, and though of large size it is a very cowardly animal, and is seldom known to attack man.

The Leopard or Panther (*Felis pardus*) is another well-known species, smaller than the Tiger, and marked with black spots in place of stripes. It is a native of all the warmer parts of the Old World.

The Ounce (*Felis uncia*) is nearly allied to the Leopard, but lives at great heights in the mountain-ranges of Central Asia. Another allied form is the Cheetah or Hunting Leopard (*Felis jubata*) of southern Asia and Africa, which is often raised to the rank of a distinct genus under the name of *Cynælurus*. It has very long legs, and the claws are only imperfectly retractile. Among the smaller Spotted Cats may be mentioned the Ocelot (*F. pardalis*), ranging from Mexico to Brazil; the *Felis viverrina* of India, China, and Malacca; and the Colocolo (*F. ferox*) of Central America.

Of the smaller *Felidæ*, the best known are the Lynxes and the Cats, properly so called. Of these the Lynxes are distinguished by their short tails, and by the fact that the ears are furnished with a pencil of hairs. They differ so much from the other *Felidæ* as to be often placed in a separate genus (*Lyncus*). The best-known species are the European Lynx (*Felis lyncus*), the Caracal (*F. caracal*) of southern Asia and Africa, and the Canadian Lynx (*F. Canadensis*) of North America. In the true Cats (*Felis catus*) the tail is long, and the ears are not tufted. The Wild Cat formerly abounded in Britain, but is now almost extinct, though it still occurs in Europe, especially in the Hartz and Carpathian Mountains. It is a large and fierce animal, and appears to be quite a match for any man not possessing firearms. It seems tolerably certain that the Wild Cat is not the original stock of the Domestic Cat, the exact origin of which is uncertain. The *Felis chaus* is the common "Jungle-cat" of India and Africa.

As regards the distribution of the *Carnivora* in *time*, the order does not appear to be represented earlier than the Eocene period, though our knowledge on this subject is certainly defective, as shown by the fact that the oldest forms at present known are referable to highly specialised groups.

The aquatic Carnivores (*Pinnipedia*) appear to commence in the Miocene Tertiary, but they are principally known as Post-tertiary fossils.

The great family of the *Ursidæ* is represented in Miocene times by the genus *Hyænarctos*. True Bears first appear during the Pliocene, and in the Post-pliocene period Europe posssessed several Bears, of which the well-known "Cave-bear (*Ursus spelæus*) is the best known.

The *Procyonidæ* are doubtfully known in deposits anterior to the Post-pliocene.

The *Mustelidæ* date back to the Miocene, but present no points of special interest.

The *Viverridæ* are an ancient group, and are represented by a number of extinct types. Two Viverrine forms (*Tylodon* and *Palæonyctis*) occur in the Eocene Tertiary of Europe; and in the Miocene are found several interesting examples of the group, of which the most remarkable is the genus *Ictitherium*, which is in some respects nearly allied to the Hyænas.

The *Hyænidæ* are not known from deposits older than the

Upper Miocene, but the best known fossil member of this family is the Cave-hyæna (*H. spelæa*) of the Post-pliocene, which is probably but a variety of the living *Hyæna crocuta*.

The family of the *Canidæ* seems to be one of the oldest of the families of the *Carnivora*, and is represented in the Eocene period by several genera (*Cynodictis*, *Galethylax*, &c.) In the later Tertiary and Post-tertiary, various extinct forms of this family are likewise known to occur.

The family of the *Hyænodontidæ* comprises certain extinct Eocene Carnivores (*Hyænodon*, *Pterodon*, &c.), in which there is the anomalous feature that *all* the præmolars and molars have cutting edges.

Lastly, the family of the *Felidæ* appears to commence in the Eocene period, the best-known extinct type of this family being the genus *Machairodus* including the so-called "sabre-toothed Tigers." In this wonderful genus we are presented with the most highly carnivorous type of all known beasts of prey. Not only are the jaws shorter in proportion than those of the most rapacious of existing *Felidæ*, but the canine teeth are of enormous size, compressed and sabre-shaped, and having their margins finely serrated. Species of *Machairodus* must have been as large as the living Lion; and the genus has an extraordinary range both in time and space, occurring in North and South America, in India, and in Europe, and extending from the Miocene to the Human period.

CHAPTER LXXVI.

RODENTIA.

ORDER XIII. RODENTIA.—The thirteenth order of *Mammalia* is that of the *Rodentia*, or Rodent Animals, often spoken of as *Glires*, comprising the Mice, Rats, Squirrels, Rabbits, Hares, Beavers, &c.

The *Rodentia* are characterised by the possession of *two long curved incisor teeth in each jaw, separated by a wide interval from the molars. The lower jaw never has more than two of these incisors, and the upper jaw very rarely; but sometimes there are four upper incisors. There are no canine teeth, and the molars and præmolars are few in number* (*rarely more than four on each side of the jaw*). *The feet are usually furnished with five toes each, all of which are armed with claws; and the hallux, when* *present, does not differ in form from the other digits. The testes pass periodically from the abdomen into a temporary scrotum, and the placenta is discoidal and deciduate.*

The most characteristic point about the Rodents is to be found in the structure of the incisors, which are adapted for continuous gnawing—hence the name of *Rodentia*. The incisor teeth are commonly two in each jaw, and they grow from persistent pulps, so that they continue to grow throughout the life of the animal. They are large, long, and curved, forming segments of a circle (fig. 438, A), and are covered anteriorly by a plate of hard enamel. The back part of each incisor is composed only of the comparatively soft dentine, so that when the tooth is exposed to attrition, the soft dentine behind wears away more rapidly than the hard enamel in front. The result of this is that the crown of the tooth acquires by use a chisel-like shape, bevelled away behind, and the enamel forms a persistent cutting-edge.

The gnawing action of the incisors is assisted by the articulation of the lower jaw, the condyle of which is placed longitudinally and not transversely, so that the jaw slides backwards and forwards. The molars, consequently, have flat crowns (fig. 438, B), the enamelled surfaces of which are always arranged in transverse ridges, in opposition to the antero-posterior movements of the jaw. The intestine is very long, and the cæcum voluminous (rarely wanting). The brain is nearly smooth, and without convolutions. The orbits are not separated from the temporal fossæ, and the eyes are directed laterally. The Rodents are almost all very small animals, and they are mostly very prolific. They subsist principally, if not entirely, upon vegetable matters, especially the harder parts of

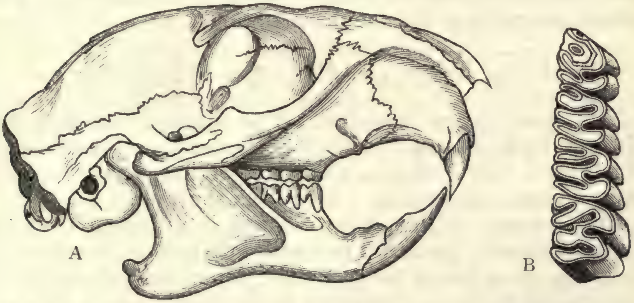

Fig. 438.—A, Side-view of the skull of *Sciurus* (*Cynomys*) *Ludovicianus*; B, Molar teeth of the upper jaw of the Beaver (*Castor fiber*). (After Giebel.)

plants, such as the bark and roots. Many of them possess the power of building elaborate nests, and most of them hibernate. They are very generally distributed over the whole world, but no member of the order has hitherto been detected in rocks older than the Eocene Tertiary.

In accordance with the number of the incisor teeth, the Rodents may be divided into the following two primary sections:—

(1.) SIMPLICIDENTATA.—Only two upper incisors, and these enamelled in front only. This division comprises all the Rodents except the *Leporidæ* and *Lagomydæ*.

(2.) DUPLICIDENTATA. — (Hares, Rabbits, and Calling Hares). Two rudimentary incisors behind the large central ones.

The order *Rodentia* comprises a very large number of families, which can be merely noticed here.

Fam. 1. *Leporidæ.*—In this family are the Hares (*Lepus timidus*) and Rabbits (*Lepus cuniculus*), distinguished amongst the Rodents by the possession of two small incisors in the upper jaw, placed behind the central chisel-shaped incisors, so that there are four upper incisors in all. The molars and præmolars are rootless, and the dental formula is—

$$i\,\frac{2-2}{1-1}\,;\ c\,\frac{0-0}{0-0}\,;\ pm\,\frac{3-3}{2-2}\,;\ m\,\frac{3-3}{3-3}=28.$$

The clavicles are imperfect. The fore-legs are furnished with five toes, and are considerably shorter than the hind-legs, which have only four toes. The two orbits communicate by an aperture in the septum. There is a short erect tail.

The common Hare (*Lepus timidus*) is dispersed over the whole of Europe, but is not met with in Northern Scandinavia, its place there being taken by the Mountain-hare (white in winter), which occurs commonly in Scotland. As a rule, the Hares occur in temperate regions, but some are found in Africa, and one species (*Lepus glacialis*) is a native of the Arctic regions, whilst the common American Hare (*L. Americanus*) extends from Canada to Mexico. The Rabbit (*Lepus cuniculus*) is also a native of temperate regions, but appears to thrive, to a more than average extent, in Australia.

Fam. 2. *Lagomydæ.*—In the Calling Hares or Pikas (*Lagomys*), which form this family, the legs do not differ much in size, there is no visible tail, and the clavicles are nearly complete. There are only five back teeth (instead of six) on each side of the upper jaw, but there are two rudimentary incisors besides the central ones. They resemble the Guinea-pigs in form, and are found in Russia, Siberia, and North America.

Fam. 3. *Caviidæ.*—In this family the tail is rudimentary; the incisors are short; the back teeth are rootless; the clavicles are rudimentary or wanting; the feet are, typically, three-toed, and the claws are in the form of hoof-like nails. They are all South American. The Capybara (*Hydrochœrus capybara*) is the largest of living Rodents, attaining a length of three or four feet. It leads a semi-aquatic life, and has the feet incompletely webbed. The *Cavia aperea* has short legs and ears, and is believed to be the parent stock of the domesticated Guinea-pigs; while other species of Cavy are also found in South America.

The Agoutis and Pacas are sometimes separated as a distinct family (*Dasyproctidæ*), having long incisors, molars at first rootless, but afterwards rooted, rudimentary clavicles, and five-toed fore-feet. The Agouti (*Dasyprocta Aguti*) is found in Guiana, Brazil, and Peru. Its fore-feet are five-toed, but the hind-feet have only three toes. The Paca (*Cœlogenys paca*) has five toes on both the hind and fore feet. It has the zygomatic arches enormously inflated, the maxillary portions being hollowed out into chambers which are lined by mucous membrane, and open into the mouth, and the use of which is quite unknown. It inhabits Central and South America.

Fam. 4. *Hystricidæ.*—In this family are the well-known Porcupines, distinguished from the other Rodents by the fact that the body is covered with long spines or "quills," mixed with bristly hairs. They have four back teeth on each side of each jaw, and they possess imperfect clavicles.

The true Porcupines (*Hystrix*) have non-prehensile tails, which are mostly furnished with long hollow spines, but sometimes with scales and bristles. As at present restricted, they are found in the Old World only. They are mostly inhabitants of hot climates, with the exception of the common Porcupine (*H. cristata*), which occurs in Southern Europe and in the north of Africa. In the genus *Atherura* of Asia and the Indian Archipelago, the tail is long and scaly, and is terminated by a bundle of flattened horny strips.

Fam. 5. *Cercolabidæ.*—This family is hardly separable from the preceding, the chief difference being that the animals composing it spend more or less of their lives in trees, and are therefore adapted for climbing. The *Cercolabidæ* comprise the American Porcupines, of which the principal genera are *Erethizon* and *Cercolabes.* In the genus *Erethizon*, represented by the Canada Porcupine (*E. dorsatum*) of North America, the quills are short, and are half hidden in the hair, and, though the animal is arboreal in habit, the tail is non-prehensile.

The nearly-allied genus *Cercolabes* or *Sphingurus* is South and Central American, and it is distinguished from the preceding by the possession of a long prehensile tail. In fact, the species of *Cercolabes*, like so many of the inhabitants of this wonderful continent, are adapted for an arboreal life, instead of being confined to the ground.

Fam. 6. *Octodontidæ.*—This family includes a large number of Rodents which are principally South American and African (*Octodon*, *Echimys*, *Ctenomys*, &c.) The best-known species is the beaver-like Coypu (*Myopotamus coypus*) of South America, in which the hind-feet are webbed, and the tail is long and rounded. It inhabits burrows in the sides of streams, and it leads a semi-aquatic life.

Among the other *Octodontidæ*, the species of *Octodon* live in South America, and are rat-like Rodents, with short tufted tails, the molars being, typically, of a simple type. In *Ctenomys*, also South American, the toes of the hind-feet carry laterally a sort of comb of bristles. The Spiny Rats (*Echimys*) are found in the West Indies and in Africa, and have the hair mixed with fine spines, while the molars have complicated enamel-folds. *Petromys* is an African type.

Fam. 7. *Chinchillidæ.*—This family includes some South American Rodents, of which the true Chinchillas (*Chinchilla*) are the best known. They are small, squirrel-like, nocturnal animals, with large ears, and excessively soft fur, strictly terrestrial in their habits, and having the hind-legs considerably longer than the fore-legs. The Alpine Viscachas (*Lagidium*) live on the Andes up to heights of 16,000 feet; and the Viscacha of the plains (*Lagostomus*) inhabits the South American pampas.

Fam. 8. *Castoridæ.*—The best-known example of this family is the beaver (*Castor fiber*). The distinctive peculiarities of the family are the presence of distinct clavicles, the possession of five toes to each foot, and the fact that the hind-feet are webbed, adapting the animal to a semi-aquatic life.

The Beaver is a large Rodent, attaining a length of from two and a half to three feet. Naturally it is a social animal, living in societies, and this is still the case in America,* but in northern Europe and Asia, where the animal has been much hunted, it leads a solitary life. When living in social communities the beavers build dams across the rivers, as well as habitations for themselves, by gnawing across the branches of trees or shrubs, and weaving them together, the whole being afterwards plastered with mud. There is no doubt but that the

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* The American Beaver is sometimes considered to be a distinct species (*Castor Canadensis*).

Beaver shows extraordinary ingenuity in these and similar operations; but there can be equally little doubt as to the greatly-exaggerated stories which have been set afloat in this connection. The tail is greatly flattened and scaly, and the animal gives the alarm by striking it upon the water. The Beaver is hunted chiefly for the sake of the skin, but also for the substance known as *castoreum*. This is a fatty substance, secreted by peculiar glands, and employed as a therapeutic agent.

Fam. 9. *Saccomydæ.*—This family comprises the so-called Pouched Rats and Gophers of North America, all of which have large external cheek-pouches. Some of them (*Geomys* and *Thomomys*) have the fore-feet greatly developed, and adapted for burrowing; whilst the so-called "Kangaroo-rats" (*Dipodomys*) have very long hind-legs, and the fore-limbs are not specially developed. The Gophers (*Geomys*, &c.) possess a pair of cheek-pouches, which are hairy inside, and open *outside* the mouth, their use being to carry provender. The best-known species is the common Pocket-gopher (*Geomys bursarius*) of the Mississippi valley and Canada.

Fam. 10. *Spalacidæ.*—Nearly related to the American Gophers are the Mole-rats (*Spalax*) of the Old World. These have a thick body, short legs, the tail rudimentary or absent, the molars rooted, and the feet five-toed. The Mole-rats are burrowing animals, in which the eyes are very small, and may be covered over by the skin, so as to be functionally useless. They live upon vegetable food, unlike the Mole, and some of them lay up a winter store. *Georychus* and *Bathyergus* are African forms of the group.

Fam. 11. *Muridæ.*—The next family of Rodents is that of the *Muridæ*, comprising the Rats, Mice, and Lemmings. In this family the tail is long, always thinly haired, sometimes naked and scaly. The lower incisors are narrow and pointed, and there are complete clavicles. The hind-feet are furnished with five toes, the fore-feet with four, together with a rudimentary pollex. The family comprises over three hundred living species, distributed over the whole world, except the islands of the Pacific, some of the species (such as the Brown Rat and the common Mouse) being similarly cosmopolitan in their range.

The Rats (*Mus rattus* and *Mus decumanus*), the common Mouse (*Mus musculus*), the Field-mouse (*Mus sylvaticus*), and the Harvest-mouse (*Mus messorius*) are all well-known examples of this family, and are too familiar to require any description. The three first are also common in North America, though not indigenous. Closely allied to the true Rats are the Hamsters (*Cricetus*, fig. 440), and the Voles (*Arvicola*); the latter represented by many species in both Europe and America. The molars of the Voles (fig. 439) are composed of alternating triangular prisms. Three species of *Arvicola* (the Water-rat, the Field-vole, and the Black Vole) are found in Britain.

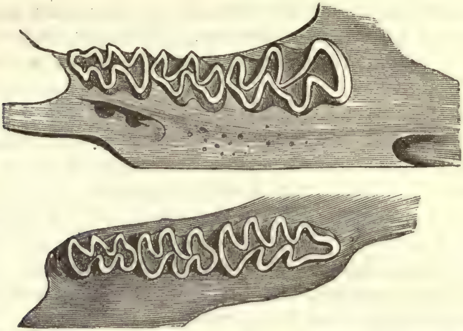

Fig. 439.—Molar teeth of the Water-rat (*Arvicola amphibius*).

A less familiar example of this family is the Lemming (*Myodes lemmus*). This curious little Rodent is found inhabiting the mountainous regions of Norway and Sweden. It is chiefly remarkable for migrating at certain periods, generally towards the approach of winter, in immense multitudes and in a straight line, apparently in obedience to some blind mechanical impulse. In these journeys the Lemmings march in parallel columns, and nothing will induce them to deviate from the straight line of march, the migration always terminating in the

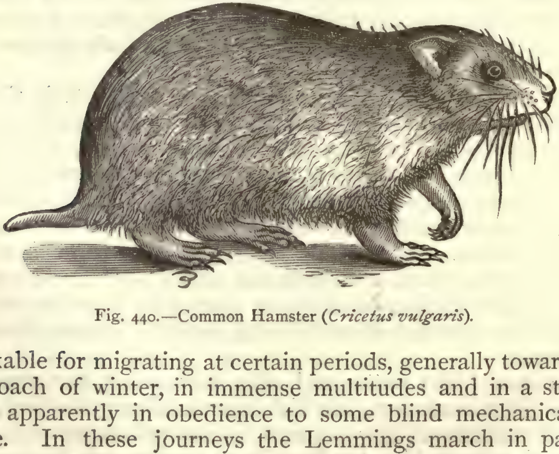

Fig. 440.—Common Hamster (*Cricetus vulgaris*).

sea, and ending in the drowning of all that have survived the journey.

The Gerbilles (*Gerbillus*), though closely related to the Jerboas, are generally placed in this family. Here also may be placed the Musquash or Ondatra (*Fiber zibethicus*) of North America, which leads a semi-aquatic life, and has the tail compressed, and the hind-feet partly webbed.

Fam. 12. *Dipodidæ.*—The next family of the Rodents is that of the *Dipodidæ* or Jerboas, mainly characterised by the disproportionate length of the hind-limbs as compared with the fore-limbs. The tail also is long and hairy, and there are complete clavicles. The Jerboas live in troops, and owing to the great length of the hind-legs, they can leap with great activity and to great distances. They are all of small size, and inhabit Russia, North Africa, and North America. The best-known members of this family are the common Jerboa (*Dipus Ægypticus*) of Africa and south-western Asia, which lives in societies and constructs burrows; the Jumping Hare (*Pedetes Capensis*) of South Africa, and the Jumping Mouse (*Zapus* or *Meriones Hudsonicus*) of North America.

Fam. 13. *Myoxidæ.*—The members of this family are commonly known as Dormice, and they are often included in the following family of the Squirrels and Marmots. They only require to be mentioned, as they must not be confounded with the true Mice (*Muridæ*) on the one hand, or the Shrew-mice (*Soricidæ*) on the other; the latter, indeed, belonging to another order (*Insectivora*). The common Dormouse (*Myoxus avellanarius*) is a British species, and must be familiarly known to almost everybody. No species of this family have yet been described from the New World. In form, the Dormice are Squirrel-like, with a long and hairy tail. There are four rooted molars on each side; the pollex is rudimentary; and the intestine is destitute of a cæcum.

Fam. 14. *Sciuridæ.*—This is one of the most characteristic and familiar of the divisions of the Rodents, and it comprises the true Squirrels, the Flying Squirrels, and the Marmots. The molars are rooted, five in number in the upper jaw on each side (the first being often deciduous), and four on each side of the lower jaw; their crowns, when unworn, being tuberculate.

The true Squirrels (*Sciurus*) are familiarly known in the person of the common British species (*Sciurus vulgaris*), and the equally common Grey Squirrel (*S. cinereus*) of the United States. Numerous species (about one hundred in number) more or less closely allied to these occur in other countries, and they are especially abundant in North America.

In the genera *Pteromys* and *Sciuropterus*, or Flying Squirrels, there is a peculiar modification by which the animal can take extended leaps from tree to tree. The skin, namely, extends in the form of a broad membrane between the hind and fore legs, and this acts as a kind of parachute, supporting the animal in the air. There is, however, no power whatever of true flight, and the structure is identically the same as what we have previously seen in the Flying Phalangers (*Petaurus*), which take the place of the Flying Squirrels on the Australian continent. The Flying Squirrels are found in southern Asia, Polynesia, the north-east of Europe, Siberia, and North America.

The Marmots (*Arctomys*), unlike the true Squirrels, are terrestrial in their habits, and live in burrows, having short tails, thick bodies, and short legs. Various intermediate forms, however, are known, by which a transition is effected between the typical Squirrels and the Marmots. Such, for example, are the Ground Squirrels (*Tamias*) of Europe, Asia, and North America. There are numerous species of this family inhabiting various parts of Europe and northern Asia, and generally distributed over the whole of North America. Good examples are the Alpine Marmot (*A. Alpinus*) of Europe, and the Prairie Dog (*Cynomys Ludovicianus*) of North America.

The Pouched Marmots (*Spermophilus*) have cheek-pouches, and are widely distributed over North America, northern Europe, and northern Asia.

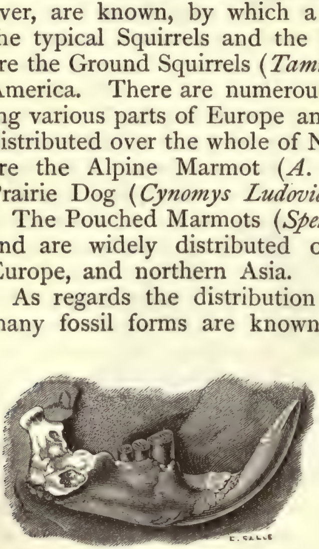

Fig. 441.—Jaw of *Trogontherium Cuvieri*. Post-pliocene.

As regards the distribution of the *Rodentia* in *time*, very many fossil forms are known, the oldest appearing in the Eocene Tertiary, but the extinct forms offer few points of special interest. The families of the *Sciuridæ*, *Muridæ*, *Myoxidæ*, and *Octodontidæ* (?), have representatives in the Eocene, and the families of the *Dipodidæ*, *Castoridæ*, *Hystricidæ*, *Cavidæ* (?), and *Lagomydæ* in the Miocene deposits. The *Leporidæ* do not seem to have made their appearance earlier than the Pliocene. Amongst the fossil Rodents perhaps the most interesting are the extinct genera of Beavers. Of these the genera *Steneofiber* and *Palæocastor* are Miocene; *Chalicomys* is Pliocene; the great *Trogontherium* (fig. 441) is Pliocene and Post-pliocene, and the equally gigantic *Castoroides* of North America is also found in the Post-pliocene deposits.

CHAPTER LXXVII.

CHEIROPTERA.

ORDER XIV. CHEIROPTERA.*—This order is undoubtedly "the most distinctly circumscribed and natural group" in the whole class of the *Mammalia*. The most obvious peculiarity of the Bats is the modification of the hand for the purpose of supporting a flying-membrane; but with this are correlated other structural characters of importance.

The *Cheiroptera* are essentially characterised by the fact that *the anterior limbs are longer than the posterior, the digits of the fore-limb, with the exception of the pollex, being enormously elongated* (fig. 442). *These elongated fingers are united by an expanded membrane or "patagium," which is also extended between the fore and hind limbs and the sides of the body, and in many cases passes also between the hind-limbs and the tail. The patagium thus formed is naked, or nearly so, on both sides, and it serves for flight. Of the fingers of the hand, the pollex, and sometimes the next finger as well, is unguiculate, or furnished with a claw; but the other digits are destitute of nails. In the hind-limbs all the toes are unguiculate, and the hallux is not in any respect different from the other digits. Well-developed clavicles are always present, and the radius has no power of rotation upon the ulna. The mammary glands are two in number, and are placed upon the chest. There are teeth of three kinds, and the canines are always well developed. The molars are tuberculate or grooved in the frugivorous forms, and cuspidate in the insectivorous species. The ulna is rudimentary. The bones are not pneumatic.* The testes are abdominal except during the breeding season. The stomach is complex and the intestine long in the fruit-eating Bats; but the reverse of this obtains amongst the insectivorous forms. The *Cheiroptera* are cosmopolitan in their distribution, and the oldest known species is from the Eocene rocks.

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* The *Cheiroptera* were placed by Linnæus in his order *Primates*, which contained also the Lemurs, the Apes, and Man.

The most striking features in the structure of the *Cheiroptera* are those connected with the conformation of the limbs (fig. 442). The fore-limb is larger than the hind-limb, the strong and moderately long humerus articulating with a very large scapula. The clavicles are complete, and the sternum is keeled. The radius is long and well developed, but the ulna is reduced to a mere splint-bone, which is anchylosed with the proximal end of the radius, all power of rotation of the fore-arm being thus lost. The thumb is short, and its last phalanx carries a claw. The index is long, but is shorter than the other digits, and often consists of its metacar-

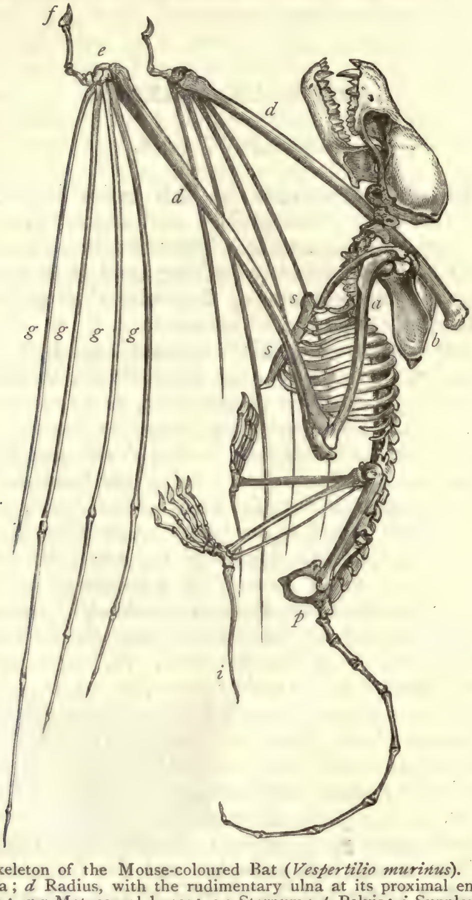

Fig. 442.—Skeleton of the Mouse-coloured Bat (*Vespertilio murinus*). *a* Humerus; *b* Scapula; *d* Radius, with the rudimentary ulna at its proximal end; *e* Carpus; *f* Thumb; *g g* Metacarpal bones; *s s* Sternum; *p* Pelvis; *i* Supplementary bone attached to the calcaneum.

pal only, in other cases with two short phalanges in addition. It is usually clawless, but may (as in most of the *Pteropidæ*) be unguiculate. Of the remaining digits the medius is the longest; and all are clawless, and possess two or three phalanges.

In the hind-limb, the fibula is mostly incomplete, and the foot is furnished with five clawed toes. To the os calcis is attached, in most Bats, a cartilaginous or bony process or spur, which is directed inwards along the lower margin of the inter-femoral membrane, and serves to put this upon the stretch during flight.

The Bats are all crepuscular and nocturnal in their habits, and are sometimes carnivorous, sometimes frugivorous. The eyes are small, but the ears are very large, and their sense of touch is most acute. During the day they retire to caves or crevices amongst the rocks, where they suspend themselves by means of the hind-feet, which are provided with curved claws. In their flight, though they can fly in the genuine and proper sense of the term, and can turn with great ease, they are by no means as rapid and as active as are the true birds. The tail is sometimes short, sometimes moderately long, and is usually included in a continuation of the leathery patagium, which stretches between the hind-legs, and is termed the "inter-femoral membrane." The body is covered with hair, but the patagium is usually hairless, or nearly so. Most of the Bats hibernate.

The *Cheiroptera* are conveniently divided into the two sections of the *Insectivora* and *Frugivora*, according as the diet consists of insects or of fruits.

SECTION A. INSECTIVORA (*Microcheiroptera*).—In this section are the four families of the *Vespertilionidæ*, *Rhinolophidæ*, *Noctilionidæ*, and *Phyllostomidæ*.

Fam. 1. *Vespertilionidæ.*—In this family are the ordinary Bats, distinguished by having a dentition very like that of the order of the Insectivorous Mammals, the molar teeth being furnished with small pointed eminences or cusps, adapted for crushing insects, and the incisors being of small size. The nose is not furnished with leaf-like appendages, and the tail is elongated, and enclosed in a large inter-femoral membrane. The species of this family are generally distributed over the temperate and warm regions of both the Old and New Worlds. About fifteen species of this family have been described as British, but of these only two are at all common. Of these two, the Pipistrelle (*Vespertilio pipistrella*) is the commonest species, occurring over the whole of Britain. The long-eared Bat (*Plecotus auritus*) is also not uncommon, and is distinguished by its greatly elongated ears, which are confluent above the forehead. The largest British species is the Noctule

(*Vespertilio noctula*), which measures as much as fifteen inches in expanse of wing.

Fam. 2. *Rhinolophidæ.*—The second family of the Insectivorous Bats is that of the *Rhinolophidæ* or Horse-shoe Bats which in most respects are very similar to the *Vespertilionidæ*, but are distinguished by the possession of a complex leaf-like apparatus appended to the nose. In the typical forms of the family the ears have no tragus or earlet. Of this family, two British species are known—the Greater and Lesser Horse-shoe Bats (*Rhinolophus ferrum-equinum* and *R. hipposideros*).

Most of the Horse-shoe Bats are Asiatic and African, a few being found in Australia. The genera *Nycteris* and *Megaderma* are sometimes separated to form a distinct family (*Nycteridæ*), distinguished by having very large ears, with a well-marked tragus or earlet.

Fam. 3. *Noctilionidæ* or *Emballonuridæ.*—In this family are a number of Bats which are principally South American, African, and Asiatic, and which are distinguished from the *Vespertilionidæ* by the fact that the tail usually perforates the inter-femoral membrane at or about its middle, and the incisors are of large size.

Fam. 4. *Phyllostomidæ.*—This is the only remaining family of the Insectivorous Bats, and comprises the well-known Vampire-bats (fig. 444, A), distinguished by having leaf-like nasal appendages, and by the fact that the ears are of small size; whereas in the preceding they are always very large (*Rhinolophus*), and are often confluent above the forehead (*Megaderma*). They are all of large size, and are natives of South America, extending northwards to Mexico and California. The Vampire-bat (*Phyllostoma spectrum*) has an expanse of wing of two feet and a half, and lives chiefly upon insects. Some species of the family have the habit of sucking the blood of sleeping animals, appearing sometimes to attack even man, though apparently never doing any substantial or lasting injury.

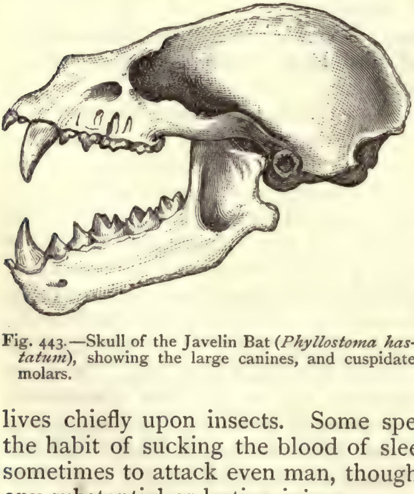

Fig. 443.—Skull of the Javelin Bat (*Phyllostoma hastatum*), showing the large canines, and cuspidate molars.

SECTION B. FRUGIVORA (*Megacheiroptera*).—In the fruit-eating section of the *Cheiroptera* are only the *Pteropidæ* or the Fox-bats, so called from the resemblance of the head to that of a fox (fig. 444, B). The head in these bats is long and pointed. The ears are simple and of moderate size, and the nose is destitute of any appendages. Cutting incisors and canines are present in both jaws, and the Fox-bats do not altogether refuse to eat small birds or mammals. They live, however, almost exclusively upon fruits, and the molars are therefore not cuspidate, but are furnished with blunt tubercular crowns. The tail is very short, or is entirely absent. The inter-femoral membrane is much reduced in size; and the index (as well as the pollex) is almost always clawed. The *Pteropidæ* are amongst the largest of the Bats, one species—the *Pteropus edulis*, or Kalong—attaining a length of from four to five feet from the tip of one wing to that of the other. The *Pteropidæ* are especially characteristic of the Pacific Archipelago—Java, Sumatra, Borneo, &c.—but they also occur in Asia, Australia, and Africa. They do not occur, however, in either North or South America.

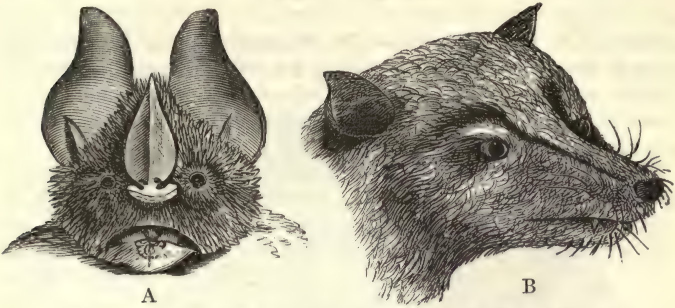

Fig. 444.—A, Head of Vampire-bat (*Alectops ater*); B, Head of Fox-bat (*Pteropus personatus*). (After Gray.)

As regards the distribution of the *Cheiroptera* in *time*, the order dates from the Eocene Tertiary, where we find the remains of *Vespertilionidæ*, essentially similar to existing forms. Professor Marsh has also detected the remains of the first American Tertiary Bats hitherto discovered in the Eocene of Wyoming. No fossil remains of *Pteropidæ* are known, but the bone-caves of Brazil (Post-pliocene) have yielded traces of several species of *Phyllostomidæ*.

CHAPTER LXXVIII.

INSECTIVORA.

ORDER XV. INSECTIVORA.—The fifteenth order of Mammals is that of the *Insectivora*, comprising a number of small Mammals which are very similar to the Rodents in many respects, but want the peculiar incisors of that order, and are likewise almost always furnished with clavicles.

In the *Insectivora, all the three kinds of teeth are usually present, but the exact nature of the dentition varies considerably in different cases. The incisors and canines present little special, but the molars* (fig. 445) *are always serrated with numerous small pointed eminences or cusps, adapted for crushing insects. With one exception* (*Potamogale*), *clavicles are always present in a complete form. All the feet are usually furnished with five toes; all the toes are furnished with claws; and the animal walks on the soles of the feet, or is plantigrade. The testes pass periodically from the abdomen into a temporary scrotum; and the placenta is deciduate and discoidal.* They are mostly nocturnal and subterranean, and generally hibernate. They are all of small size, and are found everywhere, except in the continents of South America and Australia, where their place is filled by Marsupials.

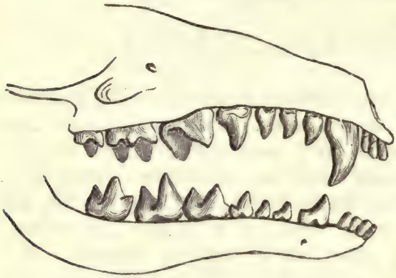
Fig. 445.—Dentition of the common Mole (*Talpa Europæa*).

The order *Insectivora* has been divided variously by different authorities, but the following are the principal families:—

Fam. 1. *Talpidæ.*—The body in this family is covered with hair; the feet are formed for digging and burrowing, and the toes are furnished with strong curved claws. There are no external ears; and the eyes in the adult are very small, or may be covered by the skin. The clavicles are strong, the arm very short, the hand wide, and the palm turned outwards and backwards. The fur is short and velvety, and the tail very short or wanting, in most cases.

The common Mole (*Talpa Europæa*, fig. 446) is the only

British species of the family, and is too well known to need any description. The dental formula of the Mole is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3} = 44.$$

The nearly-allied *Talpa cœca* of Southern Europe has the eyes covered by a membrane, pierced by a small central aperture. Other species of *Talpa* are found in India, China, and Japan.

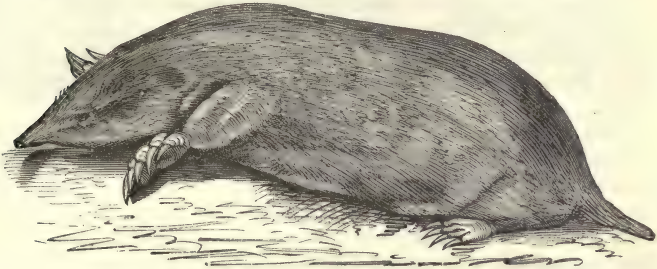

Fig. 446.—European Mole (*Talpa Europæa*).

The star-nosed Moles (*Condylura*) are North American, and are distinguished by a fringe of elongated membranous caruncles surrounding the nostrils. The tail is much longer than in the typical Moles; the eyes are very minute; and there are no external ears.

Also North American is the genus *Scalops*, comprising the so-called Shrew-moles. In this genus the tail is short, the muzzle is long, with the nostrils at its extremity, and the eyes are very small and are hidden in the fur. The common Shrew-mole (*Scalops aquaticus*) has the hind-feet webbed, and is found everywhere in the United States east of the Mississippi.

The Golden Moles (*Chrysochloris*) of South Africa are often regarded as forming a special family. They are like the Moles in form and general habit; but the hairs of the fur have the power of dispersing the rays of light, and thus of giving rise to beautiful metallic colours. The fore-feet have four toes, the second and third being very large and armed with immense claws; while the clavicles are not shortened (as they are in *Talpa*). The eyes are very minute, and covered by the skin. The dentition is quite peculiar, the dental formula being—

$$i\,\frac{3-3}{2-2};\ c\,\frac{0-0}{0-0};\ pm\,\frac{1-1}{3-3};\ m\,\frac{6-6}{5-5}\ \text{or}\ \frac{5-5}{4-4} = 36\ \text{or}\ 40.$$

Lastly, in the curious genus *Urotrichus* (sometimes referred to the *Myogalidæ*), of Japan and the north-west of America, the nose is long and cylindrical, terminated by a naked fleshy bulb, and extremely sensitive, the tail is moderately developed and hairy, and the fore-feet are adapted for burrowing. Allied forms have also been recently discovered in North China and Thibet.

Fam. 2. *Potamogalidæ.*—This family merely requires to be mentioned as founded for the reception of a single genus (*Potamogale*), comprising only a single species (*P. velox*). This animal is a curious Otter-like Insectivore, which leads a semi-aquatic life, to which end it has a long compressed tail. Clavicles are also entirely wanting. It is confined to the west of Africa.

Fam. 3. *Soricidæ.*—The *Soricidæ* or Shrew-mice are distinguished by having the body covered with hair, and the feet not adapted for digging; whilst there are mostly external ears, and the eyes are well developed. The tail is nearly naked, and scaly; the central upper and lower incisors are very large; the tibia and fibula are united; and there is no cæcum. Of all the *Insectivora*, no division is more abundant or more widely distributed than that of the Shrew-mice, their range extending over North America and the whole of the Old World. In general form and appearance the Shrews very closely resemble the true Mice (*Muridæ*) and the Dormice (*Myoxidæ*), but they are in reality widely different, and must not be confounded with them. The Common Shrew (*Sorex vulgaris*), the Garden Shrew (*Crocidura aranea*), and the Water-Shrew (*Crossopus fodiens*) are well-known British species of this family. The smallest known Mammal is one of the Shrews (*Sorex Etruscus*), which is not more than two and a half inches in length, counting in the tail.

Ths Desmans or Musk-rats, forming the genus *Myogale*, are sometimes placed here, sometimes in the family of the *Talpidæ*, and are often raised to the rank of a distinct family (*Myogalidæ*). They have the nose prolonged into a kind of flexible proboscis, whilst the feet are webbed, and the tail is compressed, thus adapting the animal for a semi-aquatic life.

The dental formula is—

$$i\,\frac{2-2}{2-2};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{5-5}{5-5};\quad m\,\frac{3-3}{3-3} = 44.$$

The central incisors and the lateral lower incisors are very large and pyramidal; and the hind-legs are longer than the fore-legs. Two species are known, one found in south-eastern Russia, the other in the Pyrenees.

Fam. 4. *Erinaceidæ.*—The fourth family of the *Insectivora* is that of the Hedgehogs, characterised by the fact that the upper part of the body is covered with prickly spines, the feet are not adapted for digging, and they have the power of rolling themselves into a ball at the approach of danger. The dental formula of the Hedgehog is—

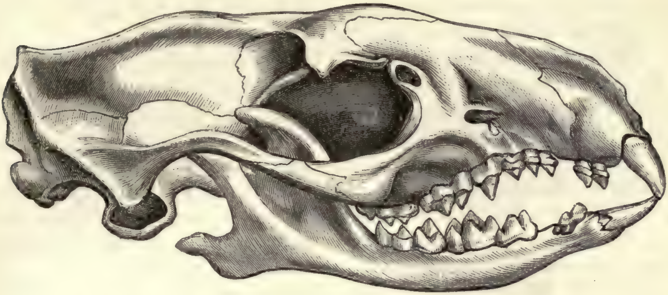

Fig. 447.—Skull of the common Hedgehog (*Erinaceus Europæus*).

$$i\,\frac{3-3}{3-3};\quad c\,\frac{0-0}{0-0};\quad pm\,\frac{4-4}{2-2};\quad m\,\frac{3-3}{3-3}=36.$$

The central upper and lower incisors are longer than the others; and the first præmolars are the largest of all the teeth present. The first upper præmolars are sometimes regarded as canines. The common Hedgehog (*Erinaceus Europæus*) is in every way a typical example of this family, but is too well known to require any description. Other species of the family are found in North and South Africa and in Asia.

Fam. 5. *Centetidæ.*—The most typical members of this family are the "Tenrecs" (*Centetes*) of Madagascar. These are small animals resembling the Hedgehogs in appearance and habits, and having the back covered with hair intermixed with fine prickles or spiny bristles, but mostly destitute of the power of rolling themselves into a ball. They have a long proboscis-like nose, and the tail is generally rudimentary or absent. The genera *Ericulus*, *Echinops*, and *Geogale* of the island of Madagascar, are allied to *Centetes*, the last having relationships with the *Soricidæ.* Likewise related to the Tenrecs is the curious genus *Solenodon* of Cuba and Hayti, in which the nose is very long and pointed, the tail is long and scaly, and the body is covered with coarse fur, without spines. The two central incisors of the lower jaw are small, and are placed between long conical lateral incisors, which are deeply grooved on their inner surfaces. We may also place here the singular *Gymnura* of Borneo, Sumatra, and the Malay Peninsula. In this genus, the body is covered with long, coarse fur, the tail is long and scaly, the snout is long, and the feet are five-toed.

Fam. 6. *Tupaiidæ.*—The best known members of this family are the "Banxrings" or "Squirrel-shrews" (*Tupaia*) of India and the Malay Archipelago. These are squirrel-like Insectivores, with long bushy tails, the feet plantigrade, five-toed, with naked soles, and sickle-shaped claws. They climb actively amongst the trees, and also run with facility upon the ground. Closely allied to the *Tupaiæ* is the little *Ptilocercus* of Borneo, in which the tail is very long, and the hairs towards its extremity are arranged like the barbs of a feather.

Fam. 7. *Macroscelidæ.*—This family includes only the little "Elephant-shrews" (*Macroscelides*) of Southern and Northern Africa. They are readily distinguished by their extraordinarily elongated trunk-like nose, resembling the proboscis of an Elephant, and their very long Kangaroo-like hind-legs.

Fam. 8. *Galeopithecidæ*—This family has been constituted for the reception of a very singular animal which forms a kind of connecting link between the orders of the *Insectivora* and *Quadrumana*, having been sometimes placed in the one and sometimes in the other, or having been regarded as the type of a separate order. The family includes only the single genus *Galeopithecus*, comprising two species of the so-called "Colugos" or "Flying Lemurs." The genus is confined to the Indian Archipelago, and the best-known species is the *Galeopithecus volans* of Malacca, Sumatra, and Borneo. The most characteristic point in this singular animal is the presence of a flying membrane, presenting some superficial resemblance to the patagium of the Bats, but in reality very much the same as the integumentary expansions of the Flying Squirrels and Flying Phalangers. This membrane in the *Galeopithecus* extends as a broad expansion from the nape of the neck to the arms, from the arms to the hind-legs, and from the hind-legs to the tail, forming an inter-femoral membrane. The fingers are not elongated, and do not support a patagium, as in the Bats, so that the animal has no power of true flight, and can simply take extended leaps from tree to tree. The feet are furnished with five toes each, united by a membrane, but neither the hallux nor the pollex are opposable to the other digits. The dental formula is—

$$i\,\frac{2-2}{3-3}\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{2-2}{2-2};\quad m\,\frac{3-3}{3-3}=34.$$

The upper incisors are separated by a wide central space, and the six lower incisors (fig. 448) are split into narrow strips, like the teeth of a comb. The *Galeopitheci* seem to live chiefly upon fruits, and other vegetable matters. They are nocturnal animals, arboreal in their habits, and they sleep head downwards, suspended by their prehensile tails.

As regards the distribution of the *Insectivora* in *time*, the earliest undoubted remains of the order occur in the Miocene, at which period the families of the *Talpidæ*, *Soricidæ*, *Erinaceidæ*, and *Centetidæ*, appear to have been already differentiated. The geological distribution of the order, however, presents no points of special interest.

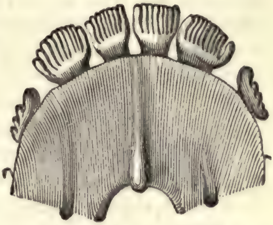

Fig. 448.—Front of the lower jaw of *Galeopithecus volans*, showing the form of the incisors. (After Owen.)

CHAPTER LXXIX.

QUADRUMANA.

ORDER XVI. QUADRUMANA.—The sixteenth order of Mammals is that of the *Quadrumana*, comprising the Apes, Monkeys, Baboons, Lemurs, &c., characterised by the following points:—

The hallux (innermost toe of the hind-limb) is separated from the other toes, and is opposable to them, so that the hind-feet become prehensile hands. The pollex (innermost toe of the fore-limbs) may be wanting, but when present, it also is usually opposable to the other digits, so that the animal becomes truly quadrumanous, or four-handed.

The incisor teeth generally are $\frac{2-2}{2-2}$, *and the molars* $\frac{3-3}{3-3}$, *with broad and tuberculate crowns. Perfect clavicles are present. The teats are two in number, and (except in Cheiromys) are pectoral in position, and the placenta is discoidal and deciduate.*

The *Quadrumana* are divided by Owen into three very natural groups, separated from one another by their anatomical characters and by their geographical distribution as follows:—

Section A. Strepsirhina.—The members of this section are characterised by the nostrils being curved or twisted, whilst the second digit of the hind-limb has a claw. This section includes the true Lemurs and a number of allied forms. It is chiefly referable to Madagascar as its geographical centre; but it spreads westwards into Africa, and eastwards into the Indian Archipelago.

Section B. Platyrhina.—This section includes those Quadrumana in which the nostrils are placed far apart; the thumbs of the fore-feet are either wanting, or, if present, are not opposable to the other digits; and the tail is generally prehensile. The Platyrhine Monkeys are exclusively confined to South America.

Section C. Catarhina.—In this section the nostrils are oblique, and placed close together. The thumb of the fore-limb (pollex), with one exception, is present, and is always opposable to the other digits. The Catarhine Monkeys are restricted entirely to the Old World, and, with the single exception of a Monkey which inhabits the Rock of Gibraltar, they are exclusively confined to Africa and Asia. It is in the Catarhine sec-

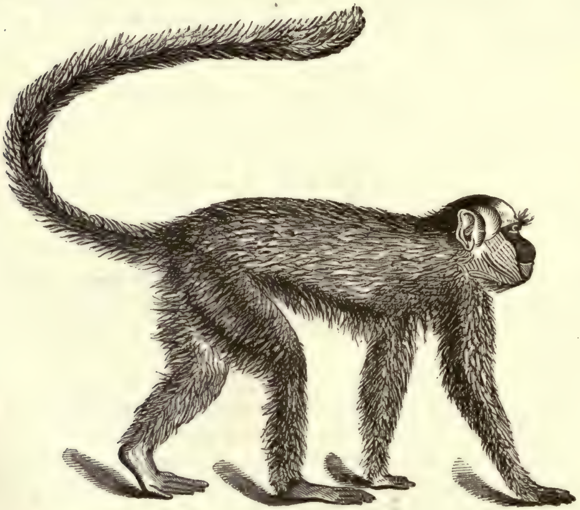

Fig. 449.—Green Monkey or Guenon (*Cercocebus sabæus*). (After Cuvier.)

tion of the *Quadrumana* that we have the highest group of the Monkeys—that, namely, of the Anthropoid or Tail-less Apes.

STREPSIRHINA.

This section of the *Quadrumana*, as before said, is characterised by the possession of twisted or curved nostrils, placed at the end of the snout. The incisor teeth are generally much modified, and are in number $\frac{3-3}{3-3}$ as a rule; the lower incisors are produced and slanting; the præmolars are $\frac{3-3}{3-3}$ or $\frac{2-2}{2-2}$, and the molars are tuberculate. The second digit of the hind-limb has a claw, and both fore and hind feet have five toes each, all the thumbs being generally opposable. In the true Lemurs, all the digits, except the second toe of the hind-feet, are furnished with nails.

This section is often called that of the *Prosimiæ*, and it includes several families, of which the Aye-ayes, Loris, and true Lemurs are the most important. In many works the *Galeopithecus* is also placed in this section.

Milne-Edwards and Gervais, from an examination of the placentation of the Lemuroids and of their cerebral characters, conclude that the group should be raised to the rank of a distinct order intermediate between the *Carnivora* and the *Quadrumana*.

The family of the Aye-ayes (*Cheiromydæ*) includes only a single animal, the *Cheiromys Madagascariensis*. In appearance the Aye-aye is not very unlike a large Squirrel, having a hairy body and a long bushy tail. There are no canines, and the molars (fig. 450) are separated by a wide interval from the incisors; while there is the additional Rodent-like character that the incisors are ploughshare-shaped, and grow from permanent pulps. The dental formula is—

$$i\,\frac{1-1}{1-1};\quad c\,\frac{0-0}{0-0};\quad pm\,\frac{1-1}{0-0};\quad m\,\frac{3-3}{3-3} = 18.$$

The fore-feet have five toes, armed with strong claws, but the pollex is scarcely opposable to the other digits. The middle finger is about as long as the ring-finger, but only about half as thick, its last two joints being hairless. The hind-feet have also five toes, of which the hallux is opposable, and the second digit is furnished with a long claw; as are all the toes except the hallux, which has a flat nail. As far as is yet known, the *Cheiromys* is entirely confined to Madagascar.

The family of the *Tarsiidæ* includes only the singular *Tarsius spectrum* of Borneo, Sumatra, Celebes, and Banca, remarkable for the extraordinary elongation of the hands and feet. It has a long tail, and is arboreal in its habits.

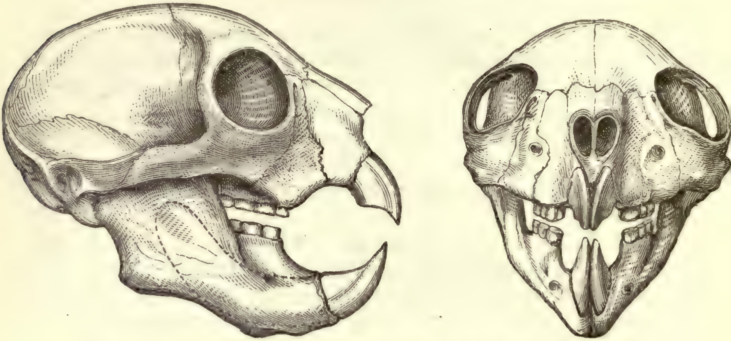

Fig. 450.—Skull of the Aye-aye (*Cheiromys*), viewed laterally and from the front. (After Owen.)

In the *Nycticebidæ* are the Loris and the Slow Lemurs, in which there is no tail, or but a rudimentary one; the limbs are nearly equal in size; the ears are short and rounded, and the eyes are large, and are placed close together. The species of this family are all of small size, and are exclusively confined to the eastern portion of the Old World, occurring in Java, Ceylon, the southern parts of Asia, and other localities in the same geographical area. They are nocturnal in their habits, living mostly on trees, and feeding upon insects; and from the slowness with which some of them progress, they are sometimes spoken of as "Slow Lemurs." The best-known species are the Slender Loris (*Loris* or *Stenops gracilis*) of Ceylon, and the *Nycticebus tardigradus* of the East Indies. Here also belong the "Potto" (*Perodicticus*) of Sierra Leone, in which the index-finger is rudimentary, and the *Arctocebus* of Old Calabar, in which this digit is completely wanting, and the tail is rudimentary.

The largest and most important of the families of the *Strepsirhina* is that of the *Lemuridæ* or Lemurs. In this family the muzzle is elongated, the feet are all furnished with opposable thumbs, and the nails on all the toes are flat, with the exception of the second toe of the hind-foot, in which there is a long and pointed claw. The body is covered with a soft fur, and the tail is usually of considerable length, and is covered with hair. They are easily domesticated; and though capable of biting pretty severely, their disposition is gentle and docile. They are mostly about the size of cats, and not unlike them in appearance, being often termed "Madagascar cats" by sailors. They are found almost exclusively in the great forests of Madagascar, moving about amongst the trees with great activity, by means of their prehensile tails. They appear to fill in Madagascar the place occupied by the higher *Quadrumana* upon the adjoining continent of Africa. One of the best-known species is the Indri (*Indris laniger*) which occurs, with other species of the genus, in Madagascar. The genus *Lemur* itself includes the so-called "Makis," the most familiar of which is the Ring-tailed Lemur (*L. catta*). The dental formula is—

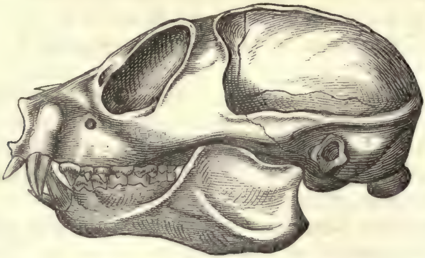

Fig. 451.—Side-view of the skull of a Lemuroid (*Nycticebus* or *Stenops tardigradus*). (After Giebel.)

$$i\,\frac{2-2}{2-2};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3}=36.$$

The "Galagos" (*Galago*), sometimes raised to the rank of a distinct family, are the only members of the *Lemuridæ* which occur out of Madagascar, and they are confined to Africa, being most abundant in the western part of this continent, but one species extending its range to Senegal and the southern borders of the Sahara. All have long bushy tails, large eyes, and large membranous ears.

PLATYRHINA.

The section of the Platyrhine Monkeys is exclusively confined to South America, and one of its leading characters is to be found in the very general possession of a prehensile tail;

this being an adaptive character by which they are suited to the arboreal life which so many of the South American Mammals are forced to lead. There are neither cheek-pouches nor natal callosities, and there is an additional præmolar, and sometimes a molar less than in Man and the Old World Monkeys. The nostrils are simple, separated by a wide septum, and opening laterally. The præmolars are $\frac{3-3}{3-3}$ in number and have blunt tubercles. The thumbs of the fore-hands are either wanting altogether, or, if present, are but slightly opposable, though versatile.

The Platyrhine Monkeys are divided into the two principal sections of the *Hapalidæ* and *Cebidæ*.

Fam. 1. *Hapalidæ* (*Arctopitheci*).—In this family the number of teeth is the same as in the Old World Monkeys and in Man, but there is an additional præmolar on each side of each jaw, and a molar less. The dental formula of the Marmoset is—

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{2-2}{2-2}=32.$$

The molars, however, are tuberculate, and though the number of teeth is the same as in the Catarhine Monkeys, in their other characters, the Marmosets are genuine Platyrhines. The hind-feet have an opposable hallux with a flat nail, but all the other toes are unguiculate, and the pollex is not at all opposable. The tail is long and thickly haired, but is not prehensile.

The *Hapalidæ* are all small monkeys, mostly about as big as Squirrels, and they are exclusively South American, occurring especially in Brazil. The best-known species is the common Marmoset (*Hapale penicillata*), but several species are domesticated and kept as pets. The genus *Midas* comprises small Monkeys which differ from the Marmosets chiefly as regards their dentition.

Fam. 2. *Cebidæ*.—In this family are all the typical Platyrhine Monkeys, in which the dentition differs from that of the *Hapalidæ*, in having an additional molar, so that the molars are the same as in the *Catarhina* and in Man, but the præmolars are more numerous. The dental formula is—

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3}=36.$$

There are neither cheek-pouches nor "callosities;" and the face is usually more or less naked, though sometimes whiskered. The tail is long, and is mostly prehensile; though in rare instances it is non-prehensile, and has its extremity clothed with hairs. The thumb of the fore-hand may be wanting, and, if present, is not opposable. All the fingers are furnished with flat nails. Their diet is miscellaneous, consisting partly of insects and partly of fruit.

The *Cebidæ* are exclusively confined to the warmer parts of South America, in the vast forests of which they are met with in large troops, climbing amongst the trees. The Spider Monkeys (*Ateles*), the Howling Monkeys (*Mycetes*), the "Sapajous" or "Capuchins" (*Cebus*), and the Squirrel Monkey (*Callithrix*), may serve as typical examples of this section of the *Quadrumana*. In *Ateles* the tail is long, slender, and powerfully prehensile; and the limbs are very long and slender. The pollex is absent, or is quite rudimentary. In *Mycetes* there is a bony drum which is formed by a convexity of the os hyoides and communicates with the larynx. The voice is thus rendered extraordinarily resonant. The pollex is not opposable, but is placed on a line with the other fingers.

In the so-called "Sakis" (*Pitheciidæ*) the tail is sometimes long (*Pithecia*), sometimes short (*Brachyurus*), but is never prehensile, while the lower incisors are inclined forwards. The little "Night-apes" (*Nyctipithecus*) also have non-prehensile tails, but the lower incisors are vertical, and the eyes, in accordance with the nocturnal habits of the animal, are of immense size.

CATARHINA.

The third and highest section of the *Quadrumana* is that of the *Catarhina* or Old World Monkeys. In this section the nostrils are oblique, and are placed close together, and the septum narium is narrow, the nostrils looking downwards. The thumbs of all the feet are opposable, so that the animal is strictly quadrumanous. In *Colobus* alone the anterior thumbs (pollex) are wanting. The dental formula is the same as in man, viz.:—

$$i\,\frac{2-2}{2-2};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{2-2}{2-2};\; m\,\frac{3-3}{3-3}=32.$$

The incisors, however, are projecting and prominent, and the canines—especially in the males—are large and pointed. Moreover, the teeth form an uneven series, interrupted by a diastema or interval. The tail is never prehensile, and is sometimes absent. Cheek-pouches* are often present, and the skin covering the *tubera ischii* is mostly callous and destitute of hair, constituting the so-called "natal callosities." With the single exception of a Monkey which inhabits the Rock of Gibraltar, all the *Catarhina*, as before remarked, are natives of Africa and Asia.

There are three well-marked groups or tribes of the Catarhine Monkeys. In the first of these the tail is long, and there are generally both cheek-pouches and natal callosities. In this tribe is the genus *Semnopithecus*, in which cheek-pouches are absent, the hind-limbs are long, and the thumb is small, and all the species of which are natives of Asia and the Indian Archipelago. One of the best-known species is the Sacred Monkey of the Hindoos (*Semnopithecus entellus*). Closely allied to the *Semnopitheci* is the genus *Colobus* of Africa, in which cheek-pouches are also absent, and in which, alone of all the Catarhine Monkeys, the pollex is either altogether absent or totally rudimentary. Closely allied to *Semnopithecus* also, is the Proboscis Monkey or Kahau (*Presbytis nasalis*), distinguished by its elongated proboscidiform nose, short pollex, and long tail. It is a native of Borneo. Here also come the little Guenons (*Cercocebus* and *Cercopithecus*, fig. 449), all of which are confined to Africa. Also referable to this division is the genus *Macacus* or *Inuus* (comprising the Macaques), which includes most of the Monkeys which are ordinarily brought to this country. It is a Macaque which occurs at the Rock of Gibraltar, and is the only wild Monkey which is found in Europe at the present day. Most of the Macaques are Asiatic, and a good example is the Wanderoo (*M. Silenus*) of India. All the Macaques have cheek-pouches and callosities, and the tail is sometimes long, sometimes rudimentary, and sometimes wanting.

The second tribe of the Catarhine Monkeys is that of the Baboons (*Cynocephalus*). In these forms the tail is mostly short, and is often quite rudimentary. The head is large, and the muzzle (fig. 452) is greatly prolonged, having the nostrils at its extremity. The facial angle is about 30°, and the whole head has much the aspect of that of a large dog. The natal callosities are generally large and conspicuous, and usually of some bright colour. The Baboons are large strong animals, extremely unattractive in outward appearance, and of great ferocity. The fore and hind limbs are nearly of equal length, and, more than any other of the Monkeys, they employ the fore-limbs in terrestrial progression, running upon all-fours with the greatest ease. They are mainly inhabitants of Africa, and one of them, the Mandrill (*Cynocephalus Maimon*), attains very nearly the height of a man. The best-known species are the Chacma (*Cynocephalus porcarius*), the Derrias or "Sacred Baboon" (*C. Hamadryas*), the common Baboon (*C. papio*), and the Mandrill. The Derrias is found in Arabia and Abyssinia, and occurs both embalmed and sculptured upon ancient monuments in Egypt and Nubia. The Mandrill is rendered probably without exception the most disgustingly hideous of living beings by the possession of large blood-red natal callosities and of enormous cheek-protuberances striped with brilliant colours in alternate ribs. The genus *Cynopithecus* includes a baboon-like monkey which is found in Celebes and the Philippine Islands.

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* The cheek-pouches are sacs or cavities in the cheeks, which open into the mouth and serve to hold any superfluous food.

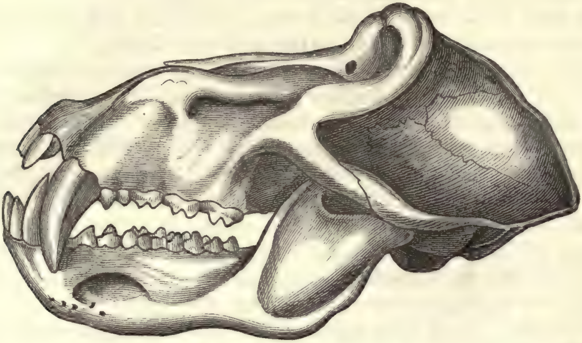

Fig. 452.—Side-view of the skull of a Baboon (*Cynocephalus ursinus*). (After Giebel.)

The third family of the Catarhine Monkeys is that of the Anthropomorphous or Anthropoid Apes, so called from their making a nearer approach in anatomical structure to Man than is the case with any other Mammal. The members of this family are Apes in which there is no tail, and cheek-pouches are absent, whilst in some cases there are also no natal callosities. They agree with Man in the possession of a broad flat sternum (whence their name of "Latisternal" Apes), in having an appendix vermiformis to the cæcum, and in the fact that the liver, except in the Gorilla, is of a very simple structure. The hind-legs are short—shorter than the fore-limbs—and the animal can progress in an erect or semi-erect position. At the same time, the thumbs of the hind-feet (hallux) are opposable to the other digits, so that the hind-feet are prehensile hands. The spine shows a single curve, and articulates with the back part of the skull. The canine teeth of the males are long, strong, and pointed, but this is not the case with the females. The structure, therefore, of the canine teeth is to be regarded in the light of a sexual peculiarity, and not as having any connection with the nature of the food.

In this tribe are the Gibbons (*Hylobates*), the Orang-utan (*Simia satyrus*), the Chimpanzee, and the Gorilla.

The Gibbons form the genus *Hylobates*, and they belong to southern Asia and the Indian Archipelago. The anterior limbs are extremely long, and the hands nearly or quite reach the ground when the animal stands in an erect posture. There is no tail, but there are natal callosities. The body is covered with a thick fur. The sternum is wider than in the other Apes, and the chin is better developed. One of the best known of the Gibbons is the Siamang (*Hylobates syndactylus*), which has been sometimes regarded as making a nearer approach to Man than any other of the Monkeys. It is a native of Sumatra. It is the largest of the Gibbons, and derives its specific name from the fact that the index and middle toes of the hind-foot are united to one another by skin as far as the nail-joint. Another well-known species is the common Gibbon (*H. lar*).

In the Orang or "Mias" (*Simia satyrus*) there are neither cheek-pouches nor natal callosities, and the hips are covered with hair. As in the Gibbons, the arms are excessively long, reaching considerably below the knee when the animal stands in an erect posture. The hind-legs are very short, and there is no tail. When full grown the Orang stands about four feet high. It never progresses with the help of a stick, or walks erect at all, except along the branches of trees, supporting itself by a higher branch, or when attacked. When young, the head of the Orang is not very different from that of an average European child; but, as the animal grows, the facial bones become gradually produced, whilst the cranium remains in a tolerably stationary condition; great bony ridges are developed for the attachment of the muscles of the jaws and face; the incisors project; and ultimately the muzzle becomes as pronounced and well-marked a feature as in the typical *Carnivora* (fig. 453, A). The Orangs are inhabitants of Sumatra and Borneo. They are arboreal in their habits, and form for themselves a sort of nest or shelter amongst the trees. The forehead is rounded, the cerebrum is greatly convoluted, and the canine teeth of the full-grown males are very large.

The genus *Troglodytes* contains the Chimpanzee (*T. niger*) and the Gorilla (*T. Gorilla*), with some other imperfectly known forms. The Chimpanzee is a native of western Africa, extending its range eastwards to Abyssinia; and has the arms much shorter, proportionately, than in the Gibbons and Orangs; still they are much longer than the hind-limbs, and they reach beneath the knee when the animal stands erect. The ears in the Chimpanzee are large, and the body is covered with dark-brown hair. The animal can stand erect, but the natural mode of progression is on all-fours. The hands are naked to the wrist, and the face is also naked, and is much wrinkled. The Chimpanzee lives in society in wooded districts, constructs huts, and can defend itself against even the largest of its foes.

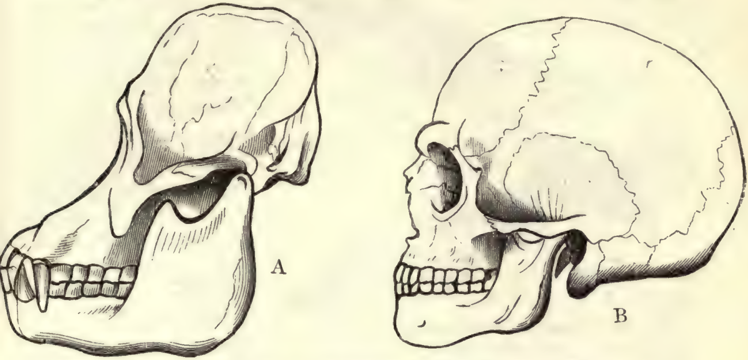

Fig. 453.—A, Skull of the Orang-utan. B, Skull of an adult European.

The Gorilla is in most respects the same as the Chimpanzee, but is much larger, attaining a height of between five and six feet. The hind-limbs are short, and the ears are small. It is an enormously strong and ferocious animal, and is found in Lower Guinea and in the interior of equatorial Africa. It possesses a laryngeal sac, has a most appalling voice, and is polygamous. Its habits are mainly arboreal, and the male builds a kind of nest in the trees, in which the female brings forth the young. The Gorilla has been often regarded as the most human of the Anthropoid Apes, but many of the highest authorities believe that the Gibbons have a greater claim to occupy this position.

As regards the distribution of the *Quadrumana* in *time*, the earliest representatives of the order appear to be found in the Eocene Tertiary. In deposits of this age in Wyoming, Professor Marsh has discovered several forms apparently related to both the Lemuroids and the Platyrhines. They form the two families of the *Lemuravidæ*, of which the principal genus (*Lemuravus*) has forty-four teeth, and *Limnotheridæ*, in which there are only forty teeth. Remains of Lemuroids have also been found in the Eocene of Europe. The first remains of the higher *Quadrumana* appear in the Miocene. The two most important of these are *Pliopithecus* (fig. 454) and *Dryopithecus*, both of which are European, and both of which belong to the section of the Catarhine Monkeys, which are at present characteristic of the Old World ; the former being most nearly allied to the living *Semnopitheci*, the latter to the Gibbons. It is interesting to notice that the South American fossil Monkeys — from the later Tertiary deposits of South America—belong to the division of the *Quadrumana* now peculiar to that continent—to the section, namely, of the Platyrhine Monkeys.

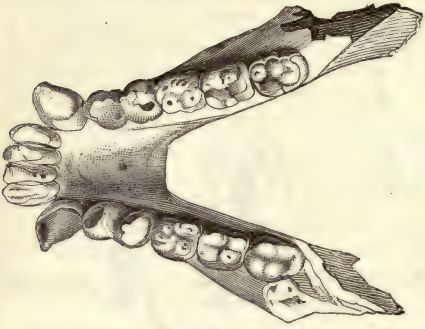
Fig. 454.—Lower jaw of *Pliopithecus antiquus*. Miocene.

CHAPTER LXXX.

BIMANA.

ORDER XVII. BIMANA.—This, the last remaining order of the *Mammalia*, comprises Man (*Homo*) alone, and it will therefore require but little notice here, the peculiarities of Man's mental and physical structure properly belonging to other branches of science.

Zoologically, Man is distinguished from all other Mammals by his habitually erect posture and bipedal progression. The lower limbs are exclusively devoted to progression and to supporting the weight of the body. The anterior limbs are shorter than the posterior, and have nothing whatever to do with progression. The thumb is opposable, and the hands are prehensile, the fingers being provided with nails. The toes of the hind-limb are also furnished with nails, but the hallux is not opposable to the other digits, and the feet are therefore useless as organs of prehension. The foot is broad and plantigrade, and the whole sole is applied to the ground in walking.

The dentition consists of thirty-two teeth, and these form a nearly even and uninterrupted series, without any interval or diastema. The dental formula is—

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{2-2}{2-2};\ m\,\frac{3-3}{3-3} = 32.$$

The brain is more largely developed and more abundantly furnished with large and deep convolutions than is the case with any other Mammal. The mammæ are pectoral, and the placenta is discoidal and deciduate.

Man is the only terrestrial Mammal in which the body is not provided, at any rate dorsally, with a covering of hair.

The zoological or *anatomical* distinctions between Man and the other Mammals are thus seen to be of no very striking nature, and certainly *of themselves* would not entitle us to consider Man as forming more than a distinct *order*. When, however, we take into account the vast and illimitable *psychical* differences, both intellectual and moral — differences which *must* entail corresponding structural distinctions — between Man and the highest *Quadrumana*, it becomes a question whether the group *Bimana* should not have the value of a distinct sub-kingdom; whilst there can be little hesitation in giving Man, at any rate, a class to himself. At any rate, man's psychical peculiarities are as much an integral portion, or more, of his totality, as are his physical characters, and, as Dr Pritchard says,—"The sentiments, feelings, sympathies, internal consciousness, and mind, and the habitudes of mind and action thence resulting, are the real and essential characteristics of humanity."

As regards the distribution of the order *Bimana* in *time*, we have doubtless yet much to learn. So far as is certainly known at present, no remains of Man, in the form of bones or implements, have as yet been detected in deposits of greater age than the later half of the Post-Pliocene period, at which time Man was associated in Western Europe with a number of extinct Mammalia.

LITERATURE.

[In addition to many of the works mentioned in the bibliographical list relating to the *Vertebrata* in general, and especially to Owen's "Comparative Anatomy and Physiology of Vertebrate Animals," and Huxley's "Manual of the Vertebrata," the following are some of the principal sources of information as to recent and fossil *Mammalia* :—]

1. "Osteology of Mammalia." Flower. 1870.
2. "Characters, Principles of Division, and Primary Groups of the Class Mammalia." Owen. 'Proc. Linn. Soc.' 1858.
3. "Saügethiere." Giebel. 'Bronn's Klassen und Ordnungen des Thierreichs.' 1874 (in course of publication).
4. "Die Saügethiere in zoologischer, anatomischer, und palæontologischer Beziehung umfassend dargestellt." Giebel. 1855.
5. "Recherches pour servir à l'histoire naturelle des Mammifères." H. & A. Milne-Edwards. 1868.
6. "Recherches sur les ossemens fossiles." Cuvier. 4th ed. 1835-37.
7. "Allgemeine Naturgeschichte." Oken. 1838.
8. "Histoire naturelle, générale et particulière." Buffon and Daubenton. 1753-67.
9. "Lectures on the Comparative Anatomy of the Placenta." Turner. 1876.
10. "Natural History of Mammalia." Waterhouse. 1845-48.
11. "Odontography." Owen. 1840-45.
12. "History of British Quadrupeds, including Cetacea." Bell. 1837.
13. "History of Quadrupeds." Bewick. 8th ed. 1824.
14. "Histoire naturelle des Mammifères." Etienne Geoffroy Saint-Hilaire, and Fred. Cuvier. 1819-35.
15. "Comparative Anatomy of the Domesticated Animals." Chauveau. Trans. by Fleming. 1873.
16. "Handbuch der Vergleichenden Anatomie der Haus-Saügethiere." Gurlt. 1860.
17. "Naturgeschichte der Saügethiere." Schreber. (Continued by Wagner.) 1775-1855.
18. "Classification of the Mammalia." Gill. 'Proc. Amer. Assoc. for the Advancement of Science.' 1870.
19. "On the Characteristics of the Primary Groups of the Class of Mammals." Gill. Ibid. 1871.
20. "Geographical Distribution of Animals." Wallace. 1876.
21. "Geographical Distribution of Mammals." Andrew Murray. 1866.
22. "Geographische Verbreitung der Thiere." Schmarda. 1853.
23. "Zoologie et Paléontologie francaises, nouvelles recherches sur les animaux vertébrés." Gervais. 2d ed. 1859.
24. "Histoire naturelle des Mammifères." Gervais. 1854.
25. "Variation of Animals and Plants under Domestication." Darwin. 1868.
26. "Mammals of North America." Baird. 1859.
27. "Mammals of India." Jerdon. 1867.
28. "Mammals of Australia." Gould. 1845-60.
29. "Fauna boreali Americana." Sir John Richardson. Mammalia by Harlan. 1825.
30. Article "Monotremata." Owen. 'Todd's Cyclopædia of Anat. and Phys.' 1841.
31. "Mammary glands of Ornithorhynchus." Owen. Phil. Trans. 1832.
32. "Young of Ornithorhynchus paradoxus." Owen. 'Trans. Zool. Soc.' 1834.
33. "Mémoire sur le genre Ornithorhynche." Van der Hoeven. 'Nova Acta Acad. Leopold.' 1823.

34. " Natural History and Habits of the Ornithorhynchus paradoxus.' E. T. Bennet. 'Trans. Zool. Soc.' 1835.
35. " Ornithorhynchi paradoxi descriptio anatomica." Meckel. 1826.
36. Article " Marsupialia." Owen. 'Todd's Cyclopædia of Anat. and Phys.' 1841.
37. " Structure of the Brain in Marsupial Animals." Owen. 'Phil. Trans.' 1837.
38. " Classification of the Marsupialia." Owen. 'Trans. Zool. Soc.' 1839.
39. " Generation of Marsupial Animals." Owen. 'Phil. Trans.' 1834.
40. " Osteology of Marsupialia." Owen. 'Trans. Zool. Soc.' 1841 and 1845.
41. " Fossil Mammalia of Australia." Owen. 'Phil. Trans.' 1858 and 1865. (*Thylacoleo.*)
42. " Fossil Mammalia of Australia." Owen. 1877.
43. " Fossil Mammalia of the Mesozoic Formations. Owen. 'Palæontographical Society.' 1871.
44. " Marsupialia." Waterhouse. 'Jardine's Naturalists' Library.' 1841.
45. " Monograph of the Macropodidæ." Gould. 1841-44.
46. " Untersuchungen über die Edentaten." Rapp. 2d ed. 1852.
47. Article " Edentata." Bell. 'Todd's Cyclopædia of Anat. and Phys.' 1836.
48. " Memoir on the Megatherium." Owen. 1860.
49. " Skeleton of the Mylodon." Owen. 1842.
50. " Memoir on the Extinct Sloth Tribe of North America." Leidy. 1853.
51. " Classification of Edentata." Turner. 'Proc. Zool. Soc.' 1851.
52. " Osteology of Edentata." Turner. 'Annals and Magazine Nat. Hist.' 1853.
53. " Form and Structure of the Manatee." Murie. 'Trans. Zool. Soc.' 1872.
54. " Ausführliche Beschreibung von sonderbaren Meerthieren." Steller. 1753.
55. " Untersuchungen über die ehemalige Verbreitung und die gänzliche Vertilgung der von Steller beobachteten Nordischen Seekuh." Von Baer. 'Mém. de l'Acad. Imp. des Sci. de St. Petersbourg.' 1838.
56. " Anatomy of the Dugong." Owen. 'Proc. Zool. Soc.' 1838.
57. Article " Cetacea." F. Cuvier. 'Todd's Cyclopædia of Anat. and Phys.' 1835. Also, " Hist. Nat. des Cétacés." 1836.
58. " Die Cetacen zoologisch-anatomisch dargestellt." Rapp. 1837.
59. " Cétácés du littoral de la Belgique." Van Beneden. 1861.
60. " Synopsis of the Species of Whales and Dolphins in the British Museum." J. E. Gray. 1868.
61. " Untersuchungen über die Nordischen Walthiere." Eschricht. 1849.
62. " Osteology of Inia and Pontoporia." Flower. 'Trans. Zool. Soc.' 1867.
63. " Monograph of the Crag Cetacea." (Ziphioid Whales.) Owen. 'Palæontographical Society.' 1870.
64. Article " Pachydermata." Rymer Jones. 'Todd's Cyclopædia of Anat. and Phys.' 1839.
65. Article " Solipedia." Rymer Jones. Ibid. 1847.
66. Article " Ruminantia." Spencer Cobbold. Ibid. 1859.
67. " The Horse." Youatt. 1843.
68. " Naturgeschichte des Pferdes." D'Alton. 1810-16.
69. " Gigantic Fossil Mammals of the Order Dinocerata." Marsh. 'Amer. Journ. Sci. and Arts.' 1873.

70. "Short-footed Ungulata of the Eocene of Wyoming." Cope. 'Proc. Amer. Philosoph. Soc.' 1873.
71. "Structure and Affinities of the Brontotheridæ." Marsh. 'Amer. Journ. Sci. and Arts.' 1874.
72. "Principal Characters of the Brontotheridæ." Marsh. 'Amer. Journ. Sci. and Arts.' 1876.
73. "Principal Characters of the Dinocerata." Marsh. 'Amer. Journ. Sci. and Arts.' 1876.
74. "Principal Characters of the Tillodontia." Marsh. 'Amer. Journ. Sci. and Arts.' 1876.
75. Article "Carnivora." Bell. 'Todd's Cyclopædia of Anat. and Phys.' 1835.
76. "Anatomie Descriptive du Chat." Strauss-Durckheim.
77. Article "Rodentia." Rymer Jones. 'Todd's Cyclopædia of Anat. and Phys.' 1847.
78. "On the Chinchillidæ." E. T. Bennett. 'Trans. Zool. Soc.' 1833.
79. "Systematisk Öfversigt af de Gnagande Däggdjuren, Glires." Lilljeborg. 1866.
80. Article "Cheiroptera." Bell. 'Todd's Cyclopædia of Anat. and Phys.' 1835.
81. "Monograph of the Asiatic Cheiroptera." Dobson. 1876.
82. "Classification of Insectivora." Mivart. 'Proc. Zool. Soc.' 1871.
83. Article "Insectivora." Bell. 'Todd's Cyclopædia of Anat. and Phys.' 1836.
84. "De Solenodonte." Brandt. 'Mém. de l'Acad. Imp. des Sci. de St. Petersbourg.' 1838.
85. Article "Quadrumana." Vrolik. 'Todd's Cyclopædia of Anat. and Phys.' 1847.
86. Article "Apes." Mivart. 'Encyclopædia Britannica.' 9th ed. 1875.
87. "Appendicular Skeleton of Primates." Mivart. 'Phil. Trans.' 1867.
88. "On the Zoological Rank of the Lemuroidea." Mivart. 'Proc. Zool. Soc.' 1873.
89. "Man and Apes." Mivart. 1874.
90. "Evidence as to Man's Place in Nature." Huxley. 1874.
91. "The Human Skeleton." Humphry. 1858.
92. "Monograph on the Aye-Aye." Owen. 1868.
93. "Recherches sur le Chimpansé." Vrolik. 1841.
94. "Natural History of Man." Pritchard. 1843.
95. "Researches into the Physical History of Mankind." Pritchard. 3d ed. 1844.
96. "De generis humani varietate nativa." Blumenbach. 3d ed. 1795.
97. "Types of Mankind." Nott and Gliddon. 1854.
98. "Descent of Man." Darwin. 1871.
99. "Fauna der Vorwelt." Giebel. 1847.
100. "Fauna Antiqua Sivalensis." Falconer and Sir Proby Cautley. 1846-49.
101. "British Fossil Mammals and Birds." Owen. 1846.
102. "Catalogue of the fossil Organic remains of Mammalia and Aves in the Museum of the Royal College of Surgeons of England." Owen. 1845.
103. "Extinct Mammalia from Nebraska Territory." Leidy. 1852.
104. "Animaux fossiles et Géologie de l'Attique." Gaudry. 1864-68.
105. "Monograph of the British Fossil Pleistocene Mammalia." Dawkins and Sandford. 'Palæontographical Society.' 1866-71.

GLOSSARY.

Abdomen (Lat. *abdomen;* from *abdo*, I conceal. Sometimes regarded as a contraction of *adipomen*, from *adeps*, fat.) The posterior cavity of the body, containing the intestines and others of the viscera.

Aberrant (Lat. *aberro*, I wander away). Departing from the regular type.

Abiogenesis (Gr. *a*, without; *bios*, life; *genesis*, origin). Spontaneous generation, or the production of living beings without pre-existent life.

Abnormal (Lat. *ab*, from; *norma*, a rule). Irregular; deviating from the ordinary standard.

Abomasum. The fourth cavity of the complex stomach of the Ruminants.

Abranchiate (Gr. *a*, without; *bragchia*, gills). Destitute of gills or branchiæ.

Acalephæ (Gr. *akalephê*, a nettle). Applied formerly to the Jelly-fishes or Sea-nettles, and other Radiate animals, in consequence of their power of stinging, derived from the presence of microscopic cells, called "thread-cells," in the integument.

Acanthocephala (Gr. *akantha*, a thorn; *kephale*, head). A class of parasitic worms, in which the head is armed with spines.

Acanthometrina (Gr. *akantha;* and *metra*, the womb). A family of *Protozoa*, characterised by having radiating siliceous spines.

Acanthopterygii (Gr. *akantha*, spine; *pterux*, wing). A group of bony fishes with spinous rays in the front part of the dorsal fin.

Acarina (Gr. *akari*, a mite). A division of the *Arachnida*, of which the Cheese-mite is the type.

Acephalous (Gr. *a*, without; *kephale*, head). Not possessing a distinct head.

Acetabula (Lat. *acetabulum*, a cup). The suckers with which the cephalic processes of many *Cephalopoda* (Cuttle-fishes) are provided.

Acetabulum. The cup-shaped socket of the hip-joint in Vertebrata.

Acontia (Gr. *akontion*, a javelin). Long filaments, charged with thread-cells, attached to the free edges of the mesenteries of Sea-anemones.

Acrita (Gr. *akritos*, confused). A term sometimes employed as synonymous with *Protozoa*, or the lowest division of the animal kingdom.

Actinomeres (Gr. *aktin*, a ray; *meros*, a part). The lobes which are mapped out on the surface of the body of the *Ctenophora*, by the ctenophores, or comb-like rows of cilia.

Actinosoma (Gr. *aktin;* and *soma*, body). Employed to designate the entire body of any *Actinozoön*, whether this be simple (as in the Sea-anemones), or composed of several zoöids (as in most Corals).

Actinotrocha (Gr. *aktin*, ray; *trochos*, wheel). The form of Invertebrate larva seen in some of the Annelides, &c., in which there is a circlet of cilia round the anterior extremity.

Actinozoa (Gr. *aktin;* and *zoön*, an animal). That division of the *Cœlenterata* of which the Sea-anemones may be taken as the type.

ADELARTHROSOMATA (Gr. *adelos*, hidden; *arthros*, joint; *soma*, body). An order of the *Arachnida*.

AGAMIC (Gr. *a*, without; *gamos*, marriage). Applied to all forms of reproduction in which the sexes are not directly concerned.

ALLANTOIDEA. The group of *Vertebrata* in which the fœtus is furnished with an allantois, comprising the Reptiles, Birds, and Mammals.

ALLANTOIS (Gr. *allas*, a sausage). One of the "membranes" of the fœtus in certain Vertebrates.

ALVEOLI (Lat. dim. of *alvus*, belly). Applied to the sockets of the teeth.

AMBULACRA (Lat. *ambulacrum*, a place for walking). The perforated spaces or "avenues" through which are protruded the tube-feet, by means of which locomotion is effected in the *Echinodermata*.

AMBULATORY (Lat. *ambulo*, I walk). Formed for walking. Applied to a single limb or to an entire animal.

AMETABOLIC (Gr. *a*, without; *metabolê*, change). Applied to those insects which do not possess wings when perfect, and which do not, therefore, pass through any marked metamorphosis.

AMNION (Gr. *amnos*, a lamb). One of the fœtal membranes of the higher Vertebrates.

AMNIOTA. The group of *Vertebrata* in which the fœtus is furnished with an amnion, comprising the Reptiles, Birds, and Mammals.

AMŒBA (Gr. *amoibos*, changing). A species of Rhizopod, so called from the numerous changes of form which it undergoes.

AMŒBIFORM. Resembling an *Amœba* in form.

AMORPHOZOA (Gr. *a*, without; *morphê*, shape; *zoōn*, animal). A name sometimes used to designate the *Sponges*.

AMPHIBIA (Gr. *amphi*, both; *bios*, life). The Frogs, Newts, and the like, which have gills when young, but can always breathe air directly when adult.

AMPHICŒLOUS (Gr. *amphi*, at both ends; *koilos*, hollow). Applied to Vertebræ which are concave at both ends.

AMPHIDISCS (Gr. *amphi*, at both ends; *diskos*, a quoit or round plate). The spicula which surround the gemmules of *Spongilla*, and resemble two toothed wheels united by an axle.

AMPHIOXUS (Gr. *amphi*, at both ends; *oxus*, sharp). The Lancelet, a little fish, which alone constitutes the order *Pharyngobranchii*.

AMPHIPNEUSTA (Gr. *amphi*, both; *pneo*, I breathe). Applied to the "perennibranchiate" Amphibians which retain their gills through life.

AMPHIPODA (Gr. *amphi*; and *pous*, a foot). An order of *Crustacea*.

ANAL (Lat. *anus*, the vent). Connected with the anus, or situated near the anus.

ANALLANTOIDEA. The group of *Vertebrata* in which the embryo is not furnished with an allantois.

ANALOGOUS. Applied to parts which perform the same function.

ANAMNIOTA. The group of *Vertebrata* in which the embryo is destitute of an amnion.

ANARTHROPODA (Gr. *a*, without; *arthros*, a joint; *pous*, foot). That division of *Annulose* animals in which there are no articulated appendages.

ANCHYLOSIS OR ANKYLOSIS (Gr. *ankulos*, crooked). The union of two bones by osseous matter, so that they become one bone, or are immovably joined together.

ANDROGYNOUS (Gr. *anēr*, a man; *gunē*, a woman). Synonymous with hermaphrodite, and implying that the two sexes are united in the same individual.

ANDROPHORES (Gr. *anēr*, a man; and *phero*, I carry). Applied to medusiform gonophores of the *Hydrozoa*, which carry the spermatozoa, and differ in form from those in which the ova are developed.

ANNELIDA (a Gallicised form of *Annulata*). The Ringed Worms, which form one of the divisions of the *Anarthropoda*.

ANNULATED. Composed of a succession of rings.

ANNULOIDA (Lat. *annulus*, a ring; Gr. *eidos*, form). The sub-kingdom comprising the *Echinodermata* and the *Scolecida* (=*Echinozoa*).

ANNULOSA (Lat. *annulus*). The sub-kingdom comprising the *Anarthropoda* and the *Arthropoda* or *Articulata*, in all of which the body is more or less evidently composed of a succession of rings.

ANOMODONTIA (Gr. *anomos*, irregular; *odous*, tooth). An extinct order of Reptiles, often called *Dicynodontia*.

ANOMURA (Gr. *anomos*, irregular; *oura*, tail). A tribe of Decapod *Crustacea*, of which the Hermit-crab is the type.

ANOPLURA (Gr. *anoplos*, unarmed; *oura*, tail). An order of Apterous Insects.

ANOURA (Gr, *a*, without; *oura*, tail). The order of *Amphibia* comprising the Frogs and Toads, in which the adult is destitute of a tail. Often called *Batrachia*.

ANTENNÆ (Lat. *antenna*, a yard-arm). The jointed horns or feelers possessed by the majority of the *Articulata*.

ANTENNULES (dim. of *antennæ*). Applied to the smaller pair of antennæ in the *Crustacea*.

ANTIBRACHIUM (Gr. *anti*, in front of; *brachion*, the arm). The fore-arm of the higher Vertebrates, composed of the *radius* and *ulna*.

ANTLERS. Properly the branches of the horns of the Deer tribe (*Cervidæ*), but generally applied to the entire horns.

ANTLIA (Lat. *antlia*, a pump). The spiral trunk or proboscis with which Butterflies and other Lepidopterous Insects suck up the juices of flowers.

APHANIPTERA (Gr. *aphanos*, inconspicuous; *pteron*, a wing). An order of Insects comprising the Fleas.

APLACENTALIA. The section of the *Mammalia*, comprising the two divisions of the *Didelphia* and *Monodelphia*, in which the young is not furnished with a placenta.

APODA (Gr. *a*, without; *podes*, feet). Applied to those fishes which have no ventral fins. Also to the footless *Cæciliæ* amongst the *Amphibia*.

APODAL. Devoid of feet.

APODEMATA (Gr. *apodaio*, I portion off). Applied to certain chitinous septa which divide the tissues in *Crustacea*.

APTERA (Gr. *a*, without; *pteron*, a wing). A division of Insects, which is characterised by the absence of wings in the adult condition.

APTEROUS. Devoid of wings.

APTERYX (Gr. *a*, without; *pterux*, a wing). A wingless bird of New Zealand, belonging to the order *Cursores*.

AQUIFEROUS (Lat. *aqua*, water; *fero*, I carry. Water-bearing: applied to all vessels or canals by which water is distributed through an organism.

ARACHNIDA (Gr. *arachné*, a spider). A class of the *Articulata*, comprising Spiders, Scorpions, and allied animals.

ARBORESCENT. Branched like a tree.

ARCHÆOPTERYX (Gr. *archaios*, ancient; *pterux*, wing). The singular fossil bird which alone constitutes the order of the *Saururæ*.

ARCHENCEPHALA (Gr. *archo*, I overrule; *egkephalos*, brain). The name applied by Owen to his fourth and highest group of *Mammalia*, comprising Man alone.

ARENACEOUS. Sandy, or composed of grains of sand.

ARTICULATA (Lat. *articulus*, a joint). A division of the animal kingdom, comprising Insects, Centipedes, Spiders, and Crustaceans, characterised by the possession of jointed bodies or jointed limbs. The term *Arthropoda* is now more usually employed.

ARTIODACTYLA (Gr. *artios*, even; *daktulos*, a finger or toe). A division of the hoofed quadrupeds (*Ungulata*) in which each foot has an even number of toes (two or four).

ASCIDIOIDA (Gr. *askos*, a bottle; *eidos*, a form). A synonym of *Tunicata*, a class of Molluscous animals, which have the shape, in many cases, of a two-necked bottle.

ASEXUAL. Applied to modes of reproduction in which the sexes are not concerned.

ASIPHONATE. Not possessing a respiratory tube or siphon. (Applied to a division of the *Lamellibranchiate* Molluscs.)

ASTEROID (Gr. *aster*, a star; and *eidos*, form). Star-shaped, or possessing radiing lobes or rays like a star-fish.

ASTEROIDEA. An order of *Echinodermata*, comprising the Star-fishes, characterised by their rayed form.

ASTOMATOUS (Gr. *a*, without; *stoma*, mouth). Not possessing a mouth.

ATLAS (Gr. the god who holds up the earth). The first vertebra of the neck, which articulates with and supports the skull.

ATRIUM (Lat. a hall). Applied to the great chamber or "cloaca," into which the intestine opens in the *Tunicata*.

AURELIA (Lat. *aurum*, gold). Applied to the chrysalides of some *Lepidoptera*, on account of their exhibiting a golden lustre.

AURICLE (Lat. dim. of *auris*, ear). Applied to one of the cavities of the heart, by which blood is driven into the ventricle.

AUTOPHAGI (Gr. *autos*, self; *phago*, I eat). Applied to birds whose young can run about and obtain food for themselves as soon as they escape from the egg.

AVES (Lat. *avis*, a bird). The class of the Birds.

AVICULARIUM (Lat. *avicula*, dim. of *avis*, a bird). A singular appendage, often shaped like the head of a bird, found in many of the *Polyzoa*.

AXIS (Gr. *axon*, a pivot). The second vertebra of the neck, upon which the skull and atlas usually rotate.

AZYGOUS (Gr. *a*, without; *zugon*, yoke). Single, without a fellow.

BACTERIUM (Gr. *bakterion*, a staff). A microscopic organism occurring in fluids containing organic matter, and having a staff-shaped form.

BALANIDÆ (Gr. *balanos*, an acorn). A family of sessile *Cirripedes*, commonly called "Acorn shells."

BALEEN (Lat. *balæna*, a whale). The horny plates which occupy the palate of the "whalebone" Whales.

BATIDES (Gr. *batos*, a bramble). The family of the *Elasmobranchii* comprising the Rays.

BATRACHIA (Gr. *batrachos*, a frog). Often loosely applied to any of the *Amphibia*, but sometimes restricted to the Amphibians as a class, or to the single order of the *Anoura*.

BELEMNITIDÆ (Gr. *belemnon*, a dart). An extinct group of Dibranchiate Cephalopods, comprising the Belemnites and their allies.

BICAVITARY (Lat. *bis*, twice; *cavus*, hollow). Consisting of or possessing two cavities.

BIFID. Cleft into two parts; forked.

BILATERAL. Having two symmetrical sides.

BIMANA (Lat. *bis*, twice; *manus*, a hand). The order of *Mammalia* comprising Man alone.

BIPEDAL (Lat. *bis*, twice; *pes*, foot). Walking upon two legs.

BIRAMOUS (Lat, *bis*, twice; *ramus*, a branch). Applied to a limb which is divided into two branches (*e.g.*, the limbs of Cirripedes).

BIVALVE (Lat. *bis*, twice; *valvæ*, folding-doors). Composed of two plates or valves; applied to the shell of the *Lamellibranchiata* and *Brachiopoda*, and to the carapace of certain *Crustacea*.

BLASTOIDEA (Gr. *blastos*, a bud; and *eidos*, form). An extinct order of *Echinodermata*, often called *Pentremites*.

BLASTOSTYLE (Gr. *blastos*, a bud; and *stulos*, a column). Applied by Prof. Allman to certain columniform zoöids in the *Hydrozoa* which are destined to bear generative buds.

BRACHIOPODA (Gr. *brachion*, an arm; *pous*, the foot). A class of the *Molluscoida*, often called "Lamp-shells," characterised by possessing two fleshy arms continued from the sides of the mouth.

BRACHIUM (Gr. *brachion*, arm). Applied to the upper arm of Vertebrates.

BRACHYURA (Gr. *brachus*, short; *oura*, tail). A tribe of the Decapod *Crustaceans* with short tails (*i.e.*, the Crabs).

BRACTS. (*See* Hydrophyllia).

BRADYPODIDÆ (Gr. *bradus*, slow; *podes*, feet). The family of *Edentata*, comprising the Sloths.

BRANCHIA (Gr. *bragchia*, the gill of a fish). A respiratory organ adapted to breathe air dissolved in water.

BRANCHIATE. Possessing gills or branchiæ.

BRANCHIFERA (Gr. *bragchia*, gill; and *phero*, I carry). A division of *Gasteropodous Molluscs*, in which the respiration is aquatic, and the respiratory organs are mostly in the form of distinct gills.

BRANCHIO-GASTEROPODA (=Branchifera).

BRANCHIOPODA (Gr. *bragchia:* and *pous*, foot). A legion of *Crustacea*, in which the gills are supported by the feet.

BRANCHIOSTEGAL (Gr. *bragchia*, gills; *stego*, I cover). Applied to a membrane and rays by which the gills are protected in many fishes.

BREVILINGUIA (Lat. *brevis*, short; *lingua*, tongue). A division of the *Lacertilia.*

BREVIPENNATÆ (Lat. *brevis*, short; *penna*, a wing). A group of the Natatorial Birds.

BRONCHI (Gr. *brogchos*, the windpipe). The branches of the windpipe (*trachea*), by which the air is conveyed to the vesicles of the lung.

BRONTOTHERIDÆ (Gr. *Brontes*, the name of a giant; *therion*, beast). An extinct order of Tertiary Mammals.

BRUTA (Lat. *brutus*, heavy, stupid). Often used to designate the Mammalian order of the *Edentata.*

BRYOZOA (Gr. *bruon*, moss; *zoön*, animal). A synonym of *Polyzoa*, a class of the *Molluscoida.*

BUCCAL (Lat. *bucca*, mouth or cheeks). Connected with the mouth.

BURSIFORM (Lat. *bursa*, a purse; *forma*, shape). Shaped like a purse; subspherical.

BYSSIFEROUS. Producing a byssus.

BYSSUS (Gr. *bussos*, flax). A term applied to the silky filaments by which the *Pinna*, the common Mussel, and certain other bivalve *Mollusca*, attach themselves to foreign objects.

CADUCIBRANCHIATE (Lat. *caducus*, falling off; Gr. *bragchia*, gill). Applied to those Amphibians in which the gills fall off before maturity is reached.

CADUCOUS. Applied to parts which fall off or are shed during the life of the animal.

CÆCAL (Lat. *cæcus*, blind). Terminating blindly, or in a closed extremity.

CÆCUM (Lat. *cæcus*). A tube which terminates blindly.

CÆSPITOSE (Lat. *cæspes*, a turf). Tufted.

CAINOZOIC. (*See* Kainozoic.)

CALCAR (Lat. a spur). Applied to the "spurs" of Rasorial Birds; and also to the rudiments of the hind-limbs in certain snakes.

CALCAREOUS (Lat. *calx*, lime). Composed of carbonate of lime.

CALICE. The little cup in which the polype of a coralligenous Zoophyte (*Actinozoön*) is contained.

CALYCOPHORIDÆ (Gr. *kalux*, a cup; and *phero*, I carry). An order of the Oceanic *Hydrozoa*, so called from their possessing bell-shaped swimming organs (*nectocalyces*).

CALYPTOBLASTIC (Gr. *kaluptos*, covered; and *blastos*, a bud). Applied by Prof. Allman to those *Hydrozoa* in which the nutritive or generative buds are provided with an external protective receptacle.

CALYX (Lat. *calyx*, a cup). Applied to the cup-shaped body of *Vorticella* (*Protozoa*), or of a *Crinoid* (*Echinodermata*).

CAMPANULARIDA (Lat. *campanula*, a bell). An order of Hydroid Zoophytes.

CANINE (Lat. *canis*, a dog). The eye-tooth of Mammals, or the tooth which is placed at or close to the præmaxillary suture in the upper jaw, and the corresponding tooth in the lower jaw.

CAPITULUM (Lat. dim. of *caput*, head). Applied to the body of a Barnacle (*Lepadidæ*), from its being supported upon a stalk or peduncle.

CARAPACE. A protective shield. Applied to the upper shell of Crabs, Lobsters, and many other *Crustacea;* also to the case with which certain of the *Infusoria* are provided. Also the upper half of the immovable case in which the body of a Chelonian is protected.

CARINATÆ (Lat. *carina*, a keel). Applied by Huxley to all those birds in which the sternum is furnished with a median ridge or keel.

CARNIVORA (Lat. *caro*, flesh; *voro*, I devour). An order of the *Mammalia*.

CARNIVOROUS (Lat. *caro*, flesh; *voro*, I devour). Feeding upon flesh.

CARNOSE (Lat. *caro*). Fleshy.

CARPOPHAGA (Gr. *karpos*, fruit; *phago*, I eat). A section of the *Marsupialia*.

CARPUS (Gr. *karpos*, the wrist). The small bones which intervene between the fore-arm and the metacarpus.

CATARHINA (Gr. *kata*, downwards; *rhines*, nostrils). A group of the *Quadrumana*.

CAUDAL (Lat. *cauda*, the tail). Belonging to the tail.

CAVICORNIA (Lat. *cavus*, hollow; *cornu*, a horn). The "hollow-horned" Ruminants, in which the horn consists of a central bony "horn-core" surrounded by a horny sheath.

CENTRUM (Gr. *kentron*, the point round which a circle is described by a pair of compasses). The central portion or "body" of a vertebra.

CEPHALIC (Gr. *kephale*, head). Belonging to the head.

CEPHALO-BRANCHIATE (Gr. *kephale;* and *bragchia*, gill). Carrying gills upon the head. Applied to a section of the *Annelida*, which, like the *Serpulæ*, have tufts of external gills placed upon the head.

CEPHALOPHORA (Gr. *kephale;* and *phero*, I carry). Used synonymously with *Encephala*, to designate those *Mollusca* which possess a distinct head.

CEPHALOPODA (Gr. *kephale;* and *podes*, feet). A class of the *Mollusca*, comprising the Cuttle-fishes and their allies, in which there is a series of arms ranged round the head.

CEPHALOTHORAX (Gr. *kephale;* and *thorax*, chest). The anterior division of the body in many *Crustacea* and *Arachnida*, which is composed of the coalesced head and chest.

CERCARIIFORM (Lat. *cercaria*, a tailed animalcule; and *forma*, shape). *Cercaria* (Gr. *kerkos*, tail) is the name of a tadpole-shaped animalcule; and the epithet "cercariiform" is applied to all organisms of a similar shape (*e.g.*, the larval Tunicates).

CERE. The naked space found at the base of the bill of some birds.

CERVICAL (Lat. *cervix*, neck). Connected with the region of the neck.

CESTOIDEA (Gr. *kestos*, a girdle). An old name for the *Tæniada*, a class of intestinal worms with flat bodies like tape (hence the name Tapeworms).

CESTRAPHORI (Gr. *kestra*, a weapon; *phero*, I carry). The group of *Elasmobranchii* represented at the present day by the Port Jackson Shark.

CETACEA (Gr. *kētos*, a whale). The order of Mammals comprising the Whales and Dolphins.

CHÆTOGNATHA (Gr. *chaite*, bristle; *gnathos*, jaw). An order of the *Anarthropoda*, comprising only the oceanic genus *Sagitta*.

CHÆTOPHORA (Gr. *chaite; phero*, I carry). Applied as a common name to the Tubiculous and Errant Annelides, both of which have bristle-bearing foot-tubercles, together with the Earth-worms and their allies (*Oligochæta*), which have locomotive bristles.

CHEIROPTERA (Gr. *cheir*, hand; *pteron*, a wing). The order of Mammals comprising the Bats.

CHELÆ (Gr. *chele*, a claw). The prehensile claws with which some of the limbs are terminated in certain *Crustacea*, such as the Crab, Lobster, &c.

CHELATE. Possessing chelæ; applied to a limb.

CHELICERÆ (Gr. *chele*, a claw; and *keras*, a horn). The prehensile claws of the Scorpion, supposed to be homologous with antennæ.

CHELONIA (Gr. *chelone*, a tortoise). The order of Reptiles comprising the Tortoises and Turtles.

CHELONOBATRACHIA (Gr. *chelone*, a tortoise; *batrachos*, a frog). Sometimes applied to the Amphibian order of the *Anoura* (Frogs and Toads).

CHILOGNATHA (Gr. *cheilos*, a lip; and *gnathos*, a jaw). An order of the *Myriapoda*.

CHILOPODA (Gr. *cheilos;* and *podes*, feet). An order of the *Myriapoda*.

CHITINE (Gr. *chiton*, a coat). The peculiar chemical principle, nearly allied to horn, which forms the exoskeleton in many Invertebrate animals, especially in the *Arthropoda* (*Crustacea*, *Insecta*, &c.).

CHLOROPHYLL (Gr. *chloros*, green; and *phullon*, a leaf). The green colouring matter of plants.

CHROMATOPHORES (Gr. *chroma*, complexion, or colour; and *phero*, I carry). Little sacs which contain pigment-granules, and are found in the integument of Cuttle-fishes and other animals.

CHRYSALIS (Gr. *chrusos*, gold). The motionless pupa of butterflies and moths, so called because sometimes exhibiting a golden lustre.

CHYLAQUEOUS FLUID. A fluid consisting partly of water derived from the exterior, and partly of the products of digestion (chyle), occupying the body-cavity or perivisceral space in many Invertebrates (*Annelids*, *Echinoderms*, &c.), and sometimes having a special canal-system for its conduction (chylaqueous canals).

CHYLE (Gr. *chulos*, juice). The milky fluid which is the result of the action of the various digestive fluids upon the food.

CHYLIFIC (Gr. *chulos*, juice [chyle]; and Lat. *facio*, I make). Producing chyle. Applied to one of the stomachs, when more than one is present. The word is of mongrel origin; and "chylopoietic" is more correct.

CHYME (Gr. *chumos*, juice). The acid pasty fluid produced by the action of the gastric juice upon the food.

CHYME-MASS. The central, semi-fluid sarcode in the interior of an *Infusorian*.

CILIA (Lat. *cilium*, an eyelash). Microscopic, hair-like filaments, which have the power of lashing backwards and forwards, thus creating currents in the surrounding or contiguous fluid, or subserving locomotion in the animal which possesses them.

CILIOGRADA (Lat. *cilium*; and *gradior*, I walk). Synonymous with *Ctenophora*, an order of *Actinozoa*.

CINCLIDES (Gr. *kigklis*, a lattice). Special apertures in the column walls of some Sea-anemones (*Actinidæ*), which probably serve for the emission of the cord-like "craspeda."

CIRRI (Lat. *cirrus*, a curl). Tendril-like appendages, such as the feet of Barnacles, and Acorn-shells (*Cirripedes*), the lateral processes on the arms of *Brachiopoda*, &c.

CIRRIFEROUS or CIRRIGEROUS. Carrying cirri.

CIRRIPEDIA, CIRRHIPEDIA, or CIRRHOPODA (Lat. *cirrus*, a curl; and *pes*, a foot). A sub-class of *Crustacea* with curled jointed feet.

CIRROSTOMI (Lat. *cirrus*, a tendril; Gr. *stoma*, mouth). Sometimes used to designate the *Pharyngobranchii*.

CLADOCERA (Gr. *klados*, a branch; *keras*, a horn). An order of *Crustacea* with branched antennæ.

CLAVATE (Lat. *clavus*, a club). Club-shaped.

CLAVICLE (Lat. *clavicula*, a little key). The "collar-bone," forming one of the elements of the pectoral arch of Vertebrates.

CLOACA (Lat. a sink). The cavity into which the intestinal canal and the ducts of the generative and urinary organs open in common, in some Invertebrates (*e.g.*, in Insects), and also in many Vertebrate animals.

CLYPEIFORM (Lat. *clypeus*, a shield; and *forma*, shaped). Shield-shaped; applied, for example, to the carapace of the King-crab.

CNIDÆ (Gr. *knide*, a nettle). The urticating cells or "thread-cells" whereby many *Cœlenterate* animals obtain their power of stinging.

COCCOLITHS (Gr. *kokkos*, a berry; *lithos*, stone). Minute oval or rounded bodies, which are found either free or attached to the surface of coccospheres, and which are probably of vegetable origin.

COCCOSPHERES (Gr. *kokkos*; and *sphaira*, a sphere). Spherical masses of sarcode, enclosed in a delicate calcareous envelope, and bearing coccoliths upon their external surface.

COCCYGEAL. Connected with the coccyx.

COCCYX (Gr. *kokkux*, a cuckoo). The terminal portion of the spinal column in man, so called from its resemblance to a cuckoo's beak.

COCOON (French, *cocon*, the cocoon of the silk-worm; connected with Fr. *coque*, shell, which is derived from the Lat. *concha*). The outer covering of silky hairs with which the pupa or chrysalis of many insects is protected. The chitinous capsules in which Leeches and Earth-worms deposit their eggs. The silken cases which Spiders weave for their eggs.

CODONOSTOMA (Gr. *kodon*, a bell; *stoma*, mouth). The aperture or mouth of the disc (nectocalyx) of a *Medusa*, or of the bell (gonocalyx) of a medusiform gonophore.

CŒLENTERATA (Gr. *koilos*, hollow; *enteron*, the bowel). The sub-kingdom which comprises the *Hydrozoa* and *Actinozoa*. Proposed by Frey and Leuckart in place of the old term *Radiata*, which included other animals as well.

CŒNENCHYMA (Gr. *koinos*, common; *enchuma*, tissue; literally, an infusion). The common calcareous tissue which unites together the various corallites of a compound corallum.

CŒNŒCIUM (Gr. *koinos*, common; *oikos*, house). The entire dermal system of any *Polyzoön;* employed in place of the terms polyzoary or polypidom.

CŒNOSARC (Gr. *koinos*, common; *sarx*, flesh). The common organised medium by which the separate polypites of a compound *Hydrozoön* are connected together.

COLEOPTERA (Gr. *koleos*, a sheath; *pteron*, wing). The order of Insects (Beetles) in which the anterior pair of wings are hardened, and serve as protective cases for the posterior pair of membranous wings.

COLLEMBOLA (Gr. *kolla*, glue; *embolos*, a sharp beak or pointed projection). An order of Apterous insects furnished with an adhesive ventral process.

COLUBRINA (Lat. *coluber*, a snake). A division of the *Ophidia.*

COLUMBACEI (Lat. *columba*, a dove). The division of Rasorial Birds comprising the Doves and Pigeons.

COLUMELLA (Lat. dim. of *columna*, a column). In Conchology, the central axis round which the whorls of a spiral univalve are wound. Amongst the *Actinozoa*, it is the central axis or pillar which is found in the centre of the visceral chamber of many corals.

COLUMN. Applied to the cylindrical body of a Sea-anemone (*Actinia*); also to the jointed stem or peduncle of the stalked *Crinoids.*

COMMENSAL (Lat. *cum*, with; *mensa*, table). Living at the same table with, a messmate: Applied to animals which live on or in other animals for part or the whole of their life, simply sharing the food of their host, without being parasitic on him.

COMMISSURAL (Lat. *committo*, I solder together). Connecting together; usually applied to the nerve-fibres which unite different ganglia.

CONCHA (Lat. a shell). The external ear by which sounds are collected and transmitted to the internal ear.

CONCHIFERA (Lat. *concha*, a shell; *fero*, I carry). Shell-fish. Applied in a restricted sense to the bivalve Molluscs, and used as a synonym for *Lamellibranchiata.*

CONDYLE (Gr. *kondulos*, a knuckle). The surface by which one bone articulates with another. Applied especially to the articular surface or surfaces by which the skull articulates with the vertebral column.

CONIROSTRES (Lat. *conus*, a cone; *rostrum*, a beak). The division of Perching Birds with conical beaks.

COPEPODA (Gr. *kope*, an oar; *podes*, feet). An order of *Crustacea.*

CORACOID (Gr. *korax*, a crow; *eidos*, form). A separate bone which enters into the composition of the pectoral arch in Birds, Reptiles, and Monotremes. In most Mammals it is a mere process of the scapula, having, in man, some resemblance in shape to the beak of a crow.

CORALLIGENOUS. Producing a corallum.

CORALLITE. The corallum secreted by an *Actinozoön* which consists of a single polype; or the portion of a composite corallum which belongs to, and is secreted by, an individual polype.

CORALLUM (from the Latin for red coral). The hard structures deposited in, or by, the tissues of an *Actinozoön*—commonly called a "coral.

CORIACEOUS (Lat. *corium*, hide). Leathery.

CORPUS CALLOSUM (Lat. the "firm body"). The great band of nervous matter which unites the two hemispheres of the cerebrum in the Mammals.

CORPUSCULATED (Lat. *corpusculum*, a little body or particle). Applied to fluids which, like the blood, contain floating solid particles or "corpuscles."

CORTICAL LAYER. The layer of consistent sarcode, which in the *Infusoria* encloses the chyme mass, and is surrounded by the cuticle. Sometimes called the "parenchyma of the body."

COSTÆ (Lat. *costa*, a rib). Applied amongst the *Crinoidea* to designate the rows of plates which succeed the inferior or basal portion of the cup (pelvis). Amongst the *Corals* the "costæ" are vertical ridges which occur on the outer surface of the theca, and mark the position of the septa within.

COSTAL (Lat. *costa*, a rib). Connected with the ribs.

CRANIUM (Gr. *kranion*, the skull). The bony or cartilaginous case in which the brain is contained.

CRASPEDA (Gr. *kraspedon*, a margin or fringe). The long, convoluted cords, containing thread-cells, which are attached to the free margins of the mesenteries of a Sea-anemone.

CREPUSCULAR (Lat. *crepusculum*, dusk). Applied to animals which are active in the dusk or twilight.

CRINOIDEA (Gr. *krinos*, a lily; *eidos*, form). An order of *Echinodermata* comprising forms which are usually stalked, and sometimes resemble lilies in shape.

CROCODILIA (Gr. *krokodeilos*, a crocodile). An order of Reptiles.

CROP. A partial dilatation of the gullet, technically called "ingluvies."

CRUSTACEA (Lat. *crusta*, a crust). A class of articulate animals, comprising Crabs, Lobsters, &c., characterised by the possession of a hard shell or crust, which they cast periodically.

CTENOCYST (Gr. *kteis*, a comb; *kustis*, a bag or cyst). The sense-organ (probably auditory) which occurs in the *Ctenophora*.

CTENOID (Gr. *kteis*, a comb; *eidos*, form). Applied to those scales of fishes, the hinder margins of which are fringed with spines or comb-like projections.

CTENOPHORA (Gr. *kteis*, a comb; and *phero*, I carry). An order of *Actinozoa*, comprising oceanic creatures, with swim by means of "ctenophores," or bands of cilia arranged in comb-like plates.

CURSORES (Lat. *curro*, I run). An order of *Aves*, comprising birds destitute of the power of flight, but formed for running vigorously (*e.g.*, the Ostrich and Emeu).

CUSPIDATE. Furnished with small pointed eminences or "cusps."

CUTICLE. (Lat. *cuticula*, dim. of *cutis*, skin). The pellicle which forms the outer layer of the body amongst the *Infusoria*. The outer layer of the integument generally.

CUTIS (Lat. skin). The inferior vascular layer of the integument, often called the *cutis vera*, the *corium*, or the *dermis*.

CYCLOID (Gr. *kuklos*, a circle; *eidos*, form). Applied to those scales of fishes which have a regularly circular or elliptical outline with an even margin.

CYCLOSTOMI (Gr. *kuklos*; and *stoma*, mouth). Sometimes used to designate the Hag-fishes and Lampreys, forming the order *Marsipobranchii*.

CYST (Gr. *kustis*, a bladder or bag). A sac or vesicle.

CYSTICA. The embryonic forms (scolices) of certain intestinal worms (Tapeworms), which were described as a distinct order, until their true nature was discovered.

CYSTOIDEA (Gr. *kustis*, a bladder; and *eidos*, form). An extinct order of *Echinodermata*.

DECAPODA (Gr. *deka*, ten; *podes*, feet). The division of *Crustacea* which have ten ambulatory feet; also the family of Cuttle-fishes, in which there are ten arms or cephalic processes.

DECIDUOUS (Lat. *decido*, I fall off). Applied to parts which fall off or are shed during the life of the animal.

DECOLLATED (Lat. *decollo*, I behead). Applied to univalve shells, the apex of which falls off in the course of growth.

DEINOCERATA or DINOCERATA (Gr. *deinos*, terrible; *keras*, horn). An extinct order of Tertiary Mammals.

DEINOSAURIA or DINOSAURIA (Gr. *deinos*, terrible; *saura*, lizard). An extinct order of Reptiles.

DENDRIFORM, DENDRITIC, DENDROID (Gr. *dendron*, a tree). Branched like a tree, arborescent.

DENTIROSTRES (Lat. *dens*, a tooth; *rostrum*, a beak). The group of Perching Birds in which the upper mandible of the beak has its lower margin toothed.

DERMA or DERMIS. (See Cutis.)

DERMAL (Gr. *derma*, skin). Belonging to the integument.

DERMOSCLERITES (Gr. *derma*, skin; *skleros*, hard). Masses of spicules which occur in the tissues of some of the *Alcyonaria* (*Actinozoa*).

DESMIDIÆ. Minute fresh-water plants, of a green colour, without a siliceous epidermis.

DEUTEROZOÖIDS (Gr. *deuteros*, second; *zoön*, animal; *eidos*, form). The zoöids which are produced by gemmation from zoöids.

DEXTRAL (Lat. *dextra*, the right hand). Right-handed; applied to the direction of the spiral in the greater number of univalve shells.

DIAPHRAGM (Gr. *diaphragma*, a partition). The "midriff," or the muscle which in *Mammalia* forms a partition between the cavities of the thorax and abdomen.

DIASTEMA (Gr. *dia*, apart; *histemi*, I place). A gap or interval, especially between teeth.

DIASTOLÉ (Gr. *diastello*, I separate or expand). The expansion of a contractile cavity such as the heart, which follows its contraction or "systolé."

DIATOMACEÆ (Gr. *diatemno*, I sever). An order of minute plants, which are provided with siliceous envelopes.

DIBRANCHIATA (Gr. *dis*, twice; *bragchia*, gill). The order of *Cephalopoda* (comprising the Cuttle-fishes, &c.) in which only two gills are present.

DICYNODONTIA (Gr. *dis*, twice; *kuon*, dog; *odous*, tooth). An extinct order of Reptiles.

DIDELPHIA (Gr. *dis*, twice; *delphus*, womb). The subdivision of Mammals comprising the Marsupials.

DIGIT (Lat. *digitus*, a finger). A finger or toe.

DIGITIGRADA (Lat. *digitus; gradior*, I walk). A subdivision of the *Carnivora*.

DIGITIGRADE. Walking upon the tips of the toes, and not upon the soles of the feet.

DIMEROSOMATA (Gr. *dis; meros*, part; *soma*, body). An order of *Arachnida*, comprising the true Spiders, so called from the marked division of the body into two regions, the cephalothorax and abdomen. The name *Araneida* is often employed for the order.

DIMYARY (Gr. *dis*, twice; *muon*, muscle). Applied to those bivalve Molluscs (*Lamellibranchiata*) in which the shell is closed by two adductor muscles.

DIŒCIOUS (Gr. *dis*, twice; *oikos*, house). Having the sexes distinct; applied to species which consist of male and female individuals.

DIPHYDONT (Gr. *dis*, twice; *phuo*, I generate; *odous*, tooth). Applied to those Mammals which have two sets of teeth.

DIPHYOZOÖIDS. Detached reproductive portions of adult *Calycophoridæ*, an order of oceanic *Hydrozoa*.

DIPNOI (Gr. *dis*, twice; *pnoé*, breath). The order of fishes represented by the *Lepidosiren*.

DIPTERA (Gr. *dis*, twice; *pteron*, wing). An order of insects characterised by the possession of two wings.

DISCOID (Gr. *diskos*, a quoit; *eidos*, form). Shaped like a round plate or quoit.

DISCOPHORA (Gr. *diskos*, a quoit; *phero*, I carry). This term is applied to the *Medusæ*, or Jelly-fishes, from their form; and is sometimes used to designate the order of the Leeches (*Hirudinea*) from the suctorial discs which these animals possess.

DISSEPIMENTS (Lat. *dissepio*, I partition off). Partitions. Used in a restricted sense to designate certain imperfect transverse partitions, which grow from the septa of many corals.

DISTAL. Applied to the quickly growing end of the hydrosoma of a *Hydro-*

zoön; the opposite, or "proximal," extremity growing less rapidly, and being the end by which the organism is fixed, when attached at all.

DIURNAL (Lat. *dies*, day). Applied to animals which are active during the day.

DIVERTICULUM (Lat. *diverticulum,* a by-road). A lateral tube with a blind extremity springing from the side of another tube.

DORSAL (Lat. *dorsum*, back). Connected with the back.

DORSIBRANCHIATE (Lat. *dorsum,* the back; Gr. *bragchia,* gill). Having external gills attached to the back; applied to certain *Annelides* and *Molluscs.* The term is of mongrel composition, and "notobranchiate" is more correctly employed.

ECDERON (Gr. *ek,* out; *deros,* skin). The outer plane of growth of the externa integumentary layer (viz., the ectoderm, or epidermis).

ECDYSIS (Gr. *ekdusis,* a stripping off). A shedding or moulting of the skin.

ECHINOCOCCI (Gr. *echinos,* a hedgehog; *kokkos,* a berry). The larval forms (scolices) of the tapeworm of the dog (*Tænia echinococcus*), commonly known as "hydatids."

ECHINODERMATA (Gr. *echinos;* and *derma,* skin). A class of animals comprising the Sea-urchins, Star-fishes, and others, most of which have spiny skins.

ECHINOIDEA (Gr. *echinos;* and *eidos,* form). An order of *Echinodermata,* comprising the Sea-urchins.

ECHINOPÆDIUM (Gr. *echinos,* a hedgehog; *paidion,* a child). A term applied to the embryo or larva of the Echinodermata.

ECHINULATE. Possessing spines.

ECTOCYST (Gr. *ektos,* outside; *kustis,* a bladder). The external investment of the cœnœcium of a *Polyzoön.*

ECTODERM (Gr. *ektos;* and *derma,* skin). The external integumentary layer of the *Cœlenterata.*

ECTOSARC (Gr. *ektos; sarx,* flesh). The outer transparent sarcode-layer of certain *Rhizopods,* such as the *Amœba.*

EDENTATA (Lat. *e,* without; *dens,* tooth). An order of *Mammalia,* often called *Bruta.*

EDENTULOUS. Toothless; without any dental apparatus. Applied to the mouth of any animal, or to the hinge of the bivalve Molluscs.

EDRIOPHTHALMATA (Gr. *hedraios,* sitting; *ophthalmos,* eye). The division of *Crustacea* in which the eyes are sessile, and are not supported upon stalks.

ELASMOBRANCHII (Gr. *elasma,* a plate; *bragchia,* gill). An order of Fishes, including the Sharks and Rays.

ELYTRA (Gr. *elutron,* a sheath). The chitinous anterior pair of wings in Beetles, which form cases for the posterior membranous wings. Also applied to the scales or plates on the back of the Sea-mouse (*Aphrodite*).

EMBRYO (Gr. *en,* in; *bruo,* I swell). The earliest stage at which the young animal is recognisable in the impregnated ovum.

ENALIOSAURIA (Gr. *enalios,* marine; *saura,* lizard). Sometimes employed as a common term to designate the extinct Reptilian orders of the *Ichthyosauria* and *Plesiosauria.*

ENCEPHALON (Gr. *egkephalos,* brain). The portion of the cerebro-spinal nervous axis contained within the cranium.

ENCEPHALOUS (Gr. *en,* in; *kephale,* the head). Possessing a distinct head. Usually applied to all the *Mollusca* proper, except the *Lamellibranchiata.*

ENCYSTATION (Gr. *en,* in; *kustis,* a bag). The transformation undergone by certain of the *Protozoa,* when they become motionless, and surround themselves by a thick coating or cyst.

ENDERON (Gr. *en,* in; *deros,* skin). The inner plane of growth of the outer integumentary layer (viz., the ectoderm or epidermis).

ENDOCYST (Gr. *endon,* within; *kustis,* a bag). The inner membrane or integumentary layer of a *Polyzoön.* In *Cristatella,* where there is no "ectocyst," the endocyst constitutes the entire integument.

ENDODERM (Gr. *endon;* and *derma,* skin). The inner integumentary layer of the *Cœlenterata.*

ENDOPODITE (Gr. *endon;* and *pous,* foot). The inner of the two secondary joints into which the typical limb of a *Crustacean* is divided.

Endosarc (Gr. *endon;* and *sarx*, flesh). The inner molecular layer of sarcode in the *Amœba*, and other allied *Rhizopods.*

Endoskeleton (Gr. *endon;* and *skeletos*, dry). The internal hard structures, such as bones, which serve for the attachment of muscles, or the protection of organs, and which are not a mere hardening of the integument.

Ensiform (Lat. *ensis*, a sword; *forma*, shape). Sword-shaped.

Entomophaga (Gr. *entoma*, insects; *phago*, I eat). A section of the Marsupialia.

Entomostraca (Gr. *entoma*, insects; *ostrakon*, a shell). Literally, shelled insects—applied to a division of *Crustacea.*

Entozoa (Gr. *entos*, within; *zoön*, animal). Animals which are parasitic in the interior of other animals.

Eocene (Gr. *eos*, dawn; *kainos*, new or recent). The lowest division of the Tertiary rocks, in which species of existing shells are to a small extent represented.

Ephippium (Gr. *ephippion;* Lat. *ephippium*, saddle). A receptacle on the back of the *Daphnia*, in which the winter eggs are deposited.

Epidermis (Gr. *epi*, upon; *derma*, the true skin). The outer non-vascular layer of the skin, often called the scarf-skin or *cuticle.*

Epimera (Gr. *epi*, upon; *mēron*, thigh). The lateral pieces of the dorsal arc of the somite of a *Crustacean.*

Epipodia (Gr. *epi*, upon; *pous*, the foot). Muscular lobes developed from the lateral and upper surfaces of the "foot" of some *Molluscs.*

Epipodite (Gr. *epi*, upon; *pous*, foot). A process developed upon the basal joint, or "protopodite," of some of the limbs of certain *Crustacea.*

Episterna (Gr. *epi*, upon; *sternon*, the breast-bone). The lateral pieces of the inferior or ventral arc of the somite of a *Crustacean.*

Epistome (Gr. *epi;* and *stoma*, mouth). A valve-like organ which arches over the mouth in certain of the *Polyzoa.*

Epitheca (Gr. *epi;* and *theke*, a sheath). A continuous layer surrounding the thecæ in some Corals externally.

Epizoa (Gr. *epi*, upon; *zoön*, animal). Animals which are parasitic upon other animals. In a restricted sense, a division of *Crustacea* which are parasitic upon fishes.

Equilateral (Lat. *æquus*, equal; *latus*, side). Having its sides equal. Usually applied to the shells of the *Brachiopoda.* When applied to the spiral shells of the *Foraminifera*, it means that all the convolutions of the shell lie in the same plane.

Equivalve (Lat. *æquus*, equal; *valvæ*, folding-doors). Applied to shells which are composed of two equal pieces or valves.

Errantia (Lat. *erro*, I wander). An order of *Annelida*, often called *Nereidea*, distinguished by their great locomotive powers.

Eurypterida (Gr. *eurus*, broad; *pteron*, wing). An extinct sub-order of *Crustacea.*

Exopodite (Gr. *exo*, outside; *pous*, foot). The outer of the two secondary joints into which the typical limb of a *Crustacean* is divided.

Exoskeleton (Gr. *exo*, outside; *skeletos*, dry). The external skeleton, which is constituted by a hardening of the integument, and is often called a "dermoskeleton."

Fasciculated (Lat. *fasciculus*, a bundle). Arranged in bundles.

Fauna (Lat. *Fauni*, the rural deities of the Romans). The general assemblage of the animals of any region or district.

Femur. The thigh-bone, intervening between the pelvis and the bones of the leg proper (*tibia* and *fibula*).

Fibula (Lat. a brooch). The outermost of the two bones of the leg in the higher *Vertebrata;* corresponding to the *ulna* of the fore-arm.

Filiform (Lat. *filum*, a thread; *forma*, shape). Thread-shaped.

Fissilinguia (Lat. *findo*, I cleave; *lingua*, tongue). A division of *Lacertilia*, with bifid tongues.

Fission (Lat. *findo*, I cleave). Multiplication by means of a process of self-division.

FISSIPAROUS (Lat. *findo;* and *pario,* I produce). Giving origin to fresh structures by a process of fission.

FISSIROSTRES (Lat. *findo,* I cleave; *rostrum,* beak). A sub-order of the Perching Birds.

FLAGELLUM (Lat. for whip). The lash-like appendage possessed by many *Infusoria,* which are therefore said to be "flagellate."

FLORA (Lat. *Flora,* the goddess of flowers). The general assemblage of the plants of any region or district.

FOOT-JAWS. The limbs of *Crustacea,* which are modified to subserve mastication.

FOOT-SECRETION. The term applied by Mr Dana to the sclerobasic corallum of certain *Actinozoa.*

FOOT-TUBERCLES. The unarticulated appendages of the *Annelida,* often called parapodia.

FORAMINIFERA (Lat. *foramen,* an aperture; *fero,* I carry). An order of *Protozoa,* usually characterised by the possession of a shell perforated by numerous pseudopodial apertures.

FRUGIVOROUS (Lat. *frux,* fruit; *voro,* I devour). Living upon fruit.

FURCULUM or FURCULA (Lat. dim. of *furca,* a fork). The "merry-thought" of birds, or the V-shaped bone formed by the united clavicles.

FUSIFORM (Lat. *fusus,* a spindle; and *forma,* shape). Spindle-shaped, or pointed at both ends.

GALLINACEI (Lat. *gallina,* a fowl). Sometimes applied to the whole order of the Rasorial Birds, but properly restricted to that section of the order of which the common Fowl is a typical example.

GANGLION (Gr. *gagglion,* a knot). A mass of nervous matter containing nerve-cells, and giving origin to nerve-fibres.

GANOID (Gr. *ganos,* splendour, brightness). Applied to those scales or plates which are composed of an inferior layer of true bone covered by a superior layer of polished enamel.

GANOIDEI. An order of Fishes.

GASTEROPODA (Gr. *gaster,* stomach; *pous,* foot). The class of the *Mollusca* comprising the ordinary univalves, in which locomotion is usually effected by a muscular expansion of the under surface of the body (the "foot").

GASTRULA (Gr. dim. of *gaster,* stomach). A name applied by Hæckel to that developmental stage in various animals, in which the embryo consists of two fundamental membranes, an outer and an inner, enclosing a central cavity.

GEMMÆ (Lat. *gemma,* a bud). The buds produced by any animal, whether detached or not.

GEMMATION. The process of producing new structures by budding.

GEMMIPAROUS (Lat. *gemma,* a bud; *pario,* I produce). Giving origin to new structures by a process of budding.

GEMMULES (Lat. dim. of *gemma*). The ciliated embryos of many *Cœlenterata;* also the seed-like reproductive bodies or "spores" of *Spongilla.*

GEPHYREA (Gr. *gephura,* a bridge). A class of the *Anarthropoda,* comprising the Spoon-worms (*Sipunculus*) and their allies.

GIZZARD. A muscular division of the stomach in Birds, Insects, &c.

GLADIUS (Lat. a sword). Applied to the horny endoskeleton or "pen" of certain Cuttle-fishes.

GLENOID (Gr. *glene,* a cavity; *eidos,* form). A shallow cavity; applied especially to the shallow articular cavity in the shoulder-blade to which the head of the humerus is jointed.

GNATHITES (Gr. *gnathos,* a jaw). The masticatory organs of *Crustacea.*

GONANGIUM (Gr. *gonos,* offspring; and *aggeion,* a vessel). The chitinous receptacle in which the reproductive buds of certain of the *Hydrozoa* are produced.

GONOBLASTIDIA (Gr. *gonos,* offspring; *blastidion,* dim. of *blastos,* a bud). The processes which carry the reproductive receptacles, or "gonophores," in many of the *Hydrozoa.*

GONOCALYX (Gr. *gonos;* and *kalux,* cup). The swimming-bell in a medusiform gonophore, or the same structure in a gonophore which is not detached.

GONOPHORE (Gr. *gonos;* and *phero,* I carry). The generative buds, or receptacles of the reproductive elements, in the *Hydrozoa,* whether these become detached or not.

GONOSOME (Gr. *gonos;* and *soma,* body). Applied as a collective term to the reproductive zoöids of a *Hydrozoön.*

GONOTHECA (Gr. *gonos;* and *theke,* a case). The chitinous receptacle within which the gonophores of certain of the *Hydrozoa* are produced.

GRALLATORES (Lat. *grallæ,* stilts). The order of the long-legged Wading Birds.

GRANIVOROUS (Lat. *granum,* a grain or seed; *voro,* I devour). Living upon grains or other seeds.

GRAPTOLITIDÆ (Gr. *grapho,* I write; *lithos,* stone). An extinct sub-class of the *Hydrozoa.*

GREGARINIDA (Lat. *gregarius,* occurring in numbers together). A class of the *Protozoa.*

GUARD. The cylindrical fibrous sheath with which the internal chambered shell (phragmacone) of a *Belemnite* is protected.

GYMNOBLASTIC (Gr. *gumnos,* naked; and *blastos,* a bud). Applied by Prof. Allman to those *Hydrozoa* in which the nutritive and reproductive buds are not protected by horny receptacles.

GYMNOLÆMATA (Gr. *gumnos,* naked; *laimos,* the throat). An order of the *Polyzoa* in which the mouth is devoid of the valvular structure known as the "epistome."

GYMNOPHIONA (Gr. *gumnos,* naked; *ophis,* a snake). The order of the *Amphibia* comprising the snake-like *Cæciliæ.*

GYMNOPHTHALMATA (Gr. *gumnos;* and *ophthalmos,* the eye). Applied by Edward Forbes to those *Medusæ* in which the eye-specks at the margin of the disc are unprotected. The division is now abandoned.

GYMNOSOMATA (Gr. *gumnos;* and *soma,* the body). The order of *Pteropoda* in which the body is not protected by a shell.

GYNOPHORES (Gr. *gune,* woman; *phero,* I carry). The generative buds, or gonophores, of *Hydrozoa,* which contain ova alone, and differ in form from those which contain spermatozoa.

GYRENCEPHALA (Gr. *guroo,* I wind about; *egkephalos,* brain). Applied by Owen to a section of the Mammalia in which the cerebral hemispheres are abundantly convoluted.

HÆMAL (Gr. *haima,* blood). Connected with the blood-vessels, or with the circulatory system.

HÆMATOCRYA (Gr. *haima,* blood; *cruos,* cold). Applied by Owen to the "cold-blooded" Vertebrates—viz., the Fishes, Amphibia, and Reptiles.

HÆMATOTHERMA (Gr. *haima,* blood; *thermos,* warm). Applied by Owen to the "warm-blooded" Vertebrates—viz., Birds and Mammals.

HALLUX (Lat. *allex,* the thumb or great toe). The innermost of the five digits which normally compose the *hind* foot of a Vertebrate animal. In man, the great toe.

HALTERES (Gr. *halteres,* weights used by athletes to steady themselves in leaping). The rudimentary filaments or "balancers" which represent the posterior pair of wings in the *Diptera,* an order of Insects.

HAUSTELLATE (Lat. *haurio,* I drink). Adapted for sucking or pumping up fluids; applied to the mouth of certain *Crustacea* and *Insecta.*

HECTOCOTYLUS (Gr. *hekaton,* a hundred; *kotulos,* a cup). The metamorphosed reproductive arm of certain of the male Cuttle-fishes. In the *Argonaut* the arm becomes detached, and was originally described as a parasitic worm.

HELIOZOA (Gr. *helios,* sun; *zoön,* animal). An order of *Protozoa,* with radiating pseudopodia.

HELMINTHOID (Gr. *helmins,* an intestinal worm). Worm-shaped, vermiform.

HEMELYTRA (Gr. *hemi,* half; *elutron,* a sheath). The wings of certain Insects, in which the apex of the wing is membranous, whilst the inner portion is chitinous, and resembles the elytron of a beetle.

HEMIMETABOLIC (Gr. *hemi,* half; *metabole,* change). Applied to those Insects which undergo an incomplete metamorphosis.

HEMIPTERA (Gr. *hemi;* and *pteron*, wing). An order of Insects in which the anterior wings are sometimes "hemelytra."

HERMAPHRODITE (Gr. *Hermes*, Mercury; *Aphrodite*, Venus). Possessing the characters of both sexes combined.

HETEROCERA (Gr. *heteros*, diverse; *keras*, horn). Applied to the Moths amongst the *Lepidoptera*, on account of the great variety of shape in their antennæ.

HETEROCERCAL (Gr. *heteros*, diverse; *kerkos*, tail). Applied to the tail of Fishes when it is unsymmetrical, or composed of two unequal lobes.

HETEROGANGLIATE (Gr. *heteros*, diverse; *gagglion*, a knot). Possessing a nervous system in which the ganglia are scattered and unsymmetrical (as in the *Mollusca*, for example).

HETEROGENESIS or HETEROGENY (Gr. *heteros*, diverse; *genesis*, origin, birth). The production of living beings without pre-existent living beings. Or, the supposed production of a living being of one kind from a part or the whole of the matter of another living being of a perfectly different kind.

HETEROMORPHIC (Gr. *heteros; morphe*, form). Differing in form and shape.

HETEROPHAGI (Gr. *heteros*, other; *phago*, I eat). Applied to Birds the young of which are born in a helpless condition, and require to be fed by the parents for a longer or shorter period.

HETEROPODA (Gr. *heteros*, diverse; *podes*, feet). An aberrant group of the Gasteropods, in which the foot is modified so as to form a swimming organ.

HEXAPOD (Gr. *hexa*, six; *pous*, foot). Possessing six legs; applied to the *Insecta.*

HILUM (Lat. *hilum*, a little thing). A small aperture (as in the gemmules of sponges), or a small depression (as in *Noctiluca*).

HIRUDINEA (Lat. *hirudo*, a horse-leech). The order of *Annelida* comprising the Leeches.

HISTOLOGY (Gr. *histos*, a web; *logos*, a discourse). The study of the tissues, more especially of the minuter elements of the body.

HOLOCEPHALI (Gr. *holos*, whole; *kephale*, head). A sub-order of the *Elasmobranchii* comprising the *Chimæræ.*

HOLOMETABOLIC (Gr. *holos*, whole; *metabole*, change). Applied to Insects which undergo a complete metamorphosis.

HOLOSTOMATA (Gr. *holos*, whole; *stoma*, mouth). A division of *Gasteropodous Molluscs*, in which the aperture of the shell is rounded, or "entire."

HOLOTHUROIDEA (Gr. *holothourion;* and *eidos*, form). An order of *Echinodermata*, comprising the Trepangs.

HOMOCERCAL (Gr. *homos*, same; *kerkos*, tail). Applied to the tail of Fishes when it is symmetrical, or composed of two equal lobes.

HOMOGANGLIATE (Gr. *homos*, like; *gagglion*, a knot). Having a nervous system in which the ganglia are symmetrically arranged (as in the *Annulosa*, for example).

HOMOLOGOUS (Gr. *homos;* and *logos*, a discourse). Applied to parts which are constructed upon the same fundamental plan.

HOMOMORPHOUS (Gr. *homos;* and *morphe*, form). Having a similar external appearance or form.

HUMERUS. The bone of the upper arm (*brachium*) in the Vertebrates.

HYALINE (Gr. *hualos*, crystal). Crystalline or glassy.

HYDATIDS (Gr. *hudatis*, a vesicle). The vesicle containing the larval forms (*Echinococci*) of the tape-worm of the dog.

HYDRAFORM. Resembling the common fresh-water polype (*Hydra*) in form.

HYDRANTH (Gr. *hudra*, water-serpent; and *anthos*, flower). The "polypite" or proper nutritive zoöid of the *Hydrozoa.*

HYDROCAULUS (Gr. *hudra*, a water-serpent; and *kaulos*, a stem). The main stem of the cœnosarc of a *Hydrozoön.*

HYDROCYSTS (Gr. *hudra;* and *kustis*, a cyst). Curious processes attached to the cœnosarc of the *Physophoridæ*, and termed "feelers" (*Fühler* and *Taster* of the Germans.

HYDRŒCIUM (Gr. *hudra;* and *oikos*, a house). The chamber into which the cœnosarc in many of the *Calycophoridæ* can be retracted.

HYDROIDA (Gr. *hudra;* and *eidos,* form). The sub-class of the *Hydrozoa,* which comprises the animals most nearly allied to the *Hydra.*

HYDROPHYLLIA (Gr. *hudra;* and *phullon,* a leaf). Overlapping appendages or plates which protect the polypites in some of the oceanic *Hydrozoa* (*Calycophoridæ* and *Physophoridæ*). They are often termed "bracts," and are the "*Deckstücke*" of the Germans.

HYDRORHIZA (Gr. *hudra;* and *rhiza,* root). The adherent base or proximal extremity of any *Hydrozoön.*

HYDROSOMA (Gr. *hudra;* and *soma,* body). The entire organism of any *Hydrozoön.*

HYDROTHECA (Gr. *hudra;* and *theke,* a case). The little chitinous cup in which the polypites of the *Sertularida* and *Campanularida* are protected.

HYDROZOA (Gr. *hudra;* and *zoön,* animal). The class of the *Cœlenterata,* which comprises animals constructed after the type of the *Hydra.*

HYMENOPTERA (Gr. *humen,* a membrane; *pteron,* a wing). An order of Insects (comprising Beetles, Ants, &c.) characterised by the possession of four membranous wings.

HYOID (Gr. *U; eidos,* form). The bone which supports the tongue in Vertebrates, and derives its name from its resemblance in man to the Greek letter U.

HYPOSTOME (Gr. *hupo,* under; *stoma,* mouth). The upper lip, or "labrum," of certain *Crustacea* (*e.g.*, Trilobites).

HYRACOIDEA (Gr. *hurax,* a shrew; *eidos,* form). An order of the *Mammalia* constituted for the reception of the single genus *Hyrax.*

ICHTHYODORULITE (Gr. *ichthus,* fish; *dorus,* spear; *lithos,* stone). The fossil fin-spines of Fishes.

ICHTHYOMORPHA (Gr. *ichthus; morphe,* shape). An order of Amphibians, often called *Urodela,* comprising the fish-like Newts, &c.

ICHTHYOPHTHIRA (Gr. *ichthus; phtheir,* a louse). An order of *Crustacea* comprising animals which are parasitic upon Fishes.

ICHTHYOPSIDA (Gr. *ichthus; opsis,* appearance). The primary division of *Vertebrata,* comprising the Fishes and Amphibia. Often spoken of as the *Branchiate Vertebrata.*

ICHTHYOPTERYGIA (Gr. *ichthus; pterux,* wing). An extinct order of Reptiles.

ICHTHYOSAURIA (Gr. *ichthus; saura,* lizard). Synonymous with *Ichthyopterygia.*

ILIUM. The haunch-bone, one of the bones of the pelvic arch in the higher Vertebrates.

IMAGO (Lat. an image or apparition). The perfect insect, after it has undergone its metamorphoses.

IMBRICATED. Applied to scales or plates which overlap one another like tiles.

INCISOR (Lat. *incido,* I cut). The cutting teeth fixed in the intermaxillary bones of the *Mammalia,* and the corresponding teeth in the lower jaw.

INEQUILATERAL. Having the two sides unequal, as in the case of the shells of the ordinary bivalves (*Lamellibranchiata*). When applied to the shells of the *Foraminifera,* it implies that the convolutions of the shell do not lie in the same plane, but are obliquely wound round an axis.

INEQUIVALVE. Composed of two unequal pieces or valves.

INFUNDIBULUM (Lat. for funnel). The tube formed by the coalescence or apposition of the epipodia in the *Cephalopoda*—commonly termed the "funnel" or "siphon."

INFUSORIA (Lat. *infusum,* an infusion). A class of *Protozoa,* so called because they are often developed in organic infusions.

INGUINAL (Lat. *inguen,* groin). Connected with, or situated upon, the groin.

INOPERCULATA (Lat. *in,* without; *operculum,* a lid). The division of pulmonate *Gasteropoda* in which there is no shelly or horny plate (operculum) by which the shell is closed when the animal is withdrawn within it.

INSECTA (Lat. *inseco,* I cut into). The class of Articulate animals commonly known as Insects.

INSECTIVORA (Lat. *insectum,* an insect; *voro,* I devour). An order of Mammals.

INSECTIVOROUS. Living upon Insects.

INSESSORES (Lat. *insedeo,* I sit upon). The order of the Perching Birds, often called *Passeres.*

INTERAMBULACRA. The rows of plates in an *Echinoderm* which are not perforated for the emission of the "tube-feet."

INTERMAXILLÆ or PRÆMAXILLÆ. The two bones which are situated between the two superior maxillæ in *Vertebrata.* In man, and some monkeys, the præmaxillæ anchylose with the maxillæ, so as to be irrecognisable in the adult.

INTUSSUSCEPTION (Lat. *intus,* within ; *suscipio,* I take up). The act of taking foreign matter into a living being.

INVERTEBRATA (Lat. *in,* without ; *vertebra,* a bone of the back). Animals without a spinal column or backbone.

ISCHIUM (Gr. *ischion,* the hip). One of the bones of the pelvic arch in Vertebrates.

ISOPODA (Gr. *isos,* equal ; *podes,* feet). An order of *Crustacea* in which the feet are all like one another and equal.

JUGULAR (Lat. *jugulum,* the throat). Connected with, or placed upon, the throat. Applied to the ventral fins of fishes when they are placed beneath or in advance of the pectorals.

KAINOZOIC (Gr. *kainos,* recent ; *zoé,* life). The Tertiary period in Geology, comprising those formations in which the organic remains approximate more or less closely to the existing fauna and flora.

KERATODE (Gr. *keras,* horn ; *eidos,* form). The horny substance of which the skeleton of many Sponges is made up.

KERATOSA. The division of Sponges in which the skeleton is composed of keratode.

LABIUM (Lat. for lip). Restricted to the lower lip of Articulate animals.

LABRUM (Lat. for lip). Restricted to the upper lip of Articulate animals.

LABYRINTHODONTIA (Gr. *laburinthos,* a labyrinth ; *odous,* tooth). An extinct order of *Amphibia,* so called from the complex microscopic structure of the teeth.

LACERTILIA (Lat. *lacerta,* a lizard). An order of *Reptilia* comprising the Lizards and Slow-worms.

LÆMODIPODA (Gr. *laimos,* throat ; *dis,* twice ; *podes,* feet). An order of *Crustacea,* so called because they have two feet placed far forwards, as it were under the throat.

LAMELLIBRANCHIATA (Lat. *lamella,* a plate ; Gr. *bragchia,* gill). The class of *Mollusca,* comprising the ordinary bivalves, characterised by the possession of lamellar gills.

LAMELLIROSTRES (Lat. *lamella,* a plate ; *rostrum,* beak). The flat-billed Swimming Birds (*Natatores*), such as Ducks, Geese, Swans, &c.

LARVA (Lat. a mask). The insect in its first stage after its emergence from the egg, when it is usually very different from the adult.

LARYNX. The upper part of the windpipe, forming a cavity with appropriate muscles and cartilages, situated beneath the hyoid bone, and concerned in Mammals in the production of vocal sounds.

LENTICULAR (Lat. *lens,* a bean). Shaped like a biconvex lens.

LEPIDOPTERA (Gr. *lepis,* a scale ; *pteron,* a wing). An order of Insects, comprising Butterflies and Moths, characterised by possessing four wings which are usually covered with minute scales.

LEPIDOTA (Gr. *lepis,* a scale). Formerly applied to the order *Dipnoi,* containing the Mud-fishes (*Lepidosiren*).

LEPTOCARDIA (Gr *leptos,* slender, small ; *cardia,* heart). The name given by Müller to the order of Fishes comprising the Lancelet, now called *Pharyngobranchii.*

LIGAMENTUM NUCHÆ (Lat. *nucha,* the nape of the neck). The band of elastic fibres by which the weight of the head in *Mammalia* is supported.

LINGUAL (Lat. *lingua,* the tongue). Connected with the tongue.

LISSENCEPHALA (Gr. *lissos,* smooth ; *egkephalos,* brain). A primary division of *Mammalia*, according to Owen, in which the cerebral hemispheres are smooth or have few convolutions.

LITHOCYSTS (Gr. *lithos*, a stone; *kustis*, a cyst). The sense-organs or "marginal bodies" of the *Lucernarida* or *Steganophthalmate Medusæ*.

LONGIPENNATÆ (Lat. *longus*, long; *penna*, wing). A group of the Natatorial Birds.

LONGIROSTRES (Lat. *longus; rostrum*, beak). A group of the Wading Birds.

LOPHOPHORE (Gr. *lophos*, a crest; and *phero*, I carry). The disc or stage upon which the tentacles of the *Polyzoa* are borne.

LOPHYROPODA (Gr. *lophouros*, having stiff hairs; and *podes*, feet). A section of *Crustacea*.

LORICA (Lat. a breast-plate). Applied to the protective case with which certain *Infusoria* are provided.

LORICATA (Lat. *lorica*, a cuirass). The division of Reptiles comprising the *Chelonia* and *Crocodilia*, in which bony plates are developed in the skin (*derma*).

LUCERNARIDA (Lat. *lucerna*, a lamp). An order of the *Hydrozoa*.

LUMBAR (Lat. *lumbus*, loin.) Connected with the loins.

LUNATE (Lat. *luna*, moon). Crescentic in shape.

LYENCEPHALA (Gr. *luo*, I loose; *egkephalos*, brain). A primary division of Mammals according to Owen.

MACRODACTYLI (Gr. *makros*, long; *daktulos*, a finger). A group of the Wading Birds.

MACRURA (Gr. *makros*, long; *oura*, tail). A tribe of Decapod *Crustaceans* with long tails (*e.g.*, the Lobster, Shrimp, &c.).

MADREPORIFORM. Perforated with small holes, like a coral; applied to the tubercle by which the ambulacral system of the *Echinoderms* mostly communicates with the exterior.

MALACOSTRACA (Gr. *malakos*, soft; *ostrakon*, shell). A division of *Crustacea*. Originally applied by Aristotle to the entire class *Crustacea*, because their shells were softer than those of the *Mollusca*.

MALLOPHAGA (Gr. *mallos*, a fleece; *phago*, I eat). An order of Insects which are mostly parasitic upon birds.

MAMMALIA (Lat. *mamma*, the breast). The class of Vertebrate animals which suckle their young.

MANDIBLE (Lat. *mandibulum*, a jaw). The upper pair of jaws in Insects; also applied to one of the pairs of jaws in *Crustacea* and Spiders, to the beak of Cephalopods, the lower jaw of Vertebrates, &c.

MANTLE. The external integument of most of the Mollusca, which is largely developed, and forms a cloak in which the viscera are protected. Technically called the "pallium."

MANUBRIUM (Lat. a handle). The polypite which is suspended from the roof of the swimming-bell of a *Medusa*, or from the gonocalyx of a medusiform gonophore amongst the *Hydrozoa*.

MANUS (Lat. the hand). The hand or fore-foot of the higher Vertebrates.

MARSIPOBRANCHII (Gr. *marsipos*, a pouch; *bragchia*, gill). The order of Fishes comprising the Hag-fishes and Lampreys with pouch-like gills.

MARSUPIALIA (Lat. *marsupium*, a pouch). An order of Mammals in which the females mostly have an abdominal pouch in which the young are carried.

MASTAX (Gr. mouth). The muscular pharynx or "buccal funnel" into which the mouth opens in most of the *Rotifera*.

MASTICATORY (Lat. *mastico*, I chew). Applied to parts adapted for chewing.

MAXILLÆ (Lat. jaws). The inferior pair or pairs of jaws in the *Arthropoda* (Insects, Crustacea, &c.). The upper jaw-bones of Vertebrates.

MAXILLIPEDES (Lat. *maxillæ*, jaws; *pes*, the foot). The limbs in *Crustacea* and *Myriapoda* which are converted into masticatory organs, and are commonly called "foot-jaws."

MEDULLA (Lat. marrow). Applied to the marrow of bones; or to the spinal cord, with or without the adjective "*spinalis*."

MEDUSÆ. An order of *Hydrozoa*, commonly known as Jelly-fishes (*Disco-*

phora, or *Acalephæ*), so called because of the resemblance of their tentacles to the snaky hair of the Medusa. Many *Medusæ* are now known to be merely the gonophores of *Hydrozoa*.

MEDUSIFORM. Resembling a *Medusa* in shape.

MEDUSOID. Like a *Medusa;* used substantively to designate the medusiform gonophores of the *Hydrozoa*.

MEMBRANA NICTITANS (Lat. *nicto*, I wink). The third eyelid of Birds, &c.

MENTUM (Lat. the chin). The basal portion of the labium or lower lip in Insects.

MEROSTOMATA (Gr. *mēron*, thigh; *stoma*, mouth). An order of *Crustacea* in which the appendages which are placed round the mouth, and which officiate as jaws, have their free extremities developed into walking or prehensile organs.

MESENTERIES (Gr. *mesos*, intermediate; *enteron*, intestine). In a restricted sense, the vertical plates which divide the somatic cavity of a Sea-anemone (*Actinia*) into chambers.

MESOPODIUM (Gr. *mesos*, middle; *pous*, foot). The middle portion of the "foot of Molluscs."

MESOSTERNUM (Gr. *mesos*, intermediate; *sternon*, the breast-bone). The middle portion of the sternum, intervening between the attachment of the second pair of ribs and the xiphoid cartilage (*xiphisternum*).

MESOTHORAX (Gr. *mesos;* and *thorax*, the chest). The middle ring of the thorax in Insects.

MESOZOIC (Gr. *mesos;* and *zoē*, life). The Secondary period in Geology.

METACARPUS (Gr. *meta*, after; *karpos*, the wrist). The bones which form the "root of the hand," and intervene between the wrist and the fingers.

METAMORPHOSIS (Gr. *meta*, implying change; *morphe*, shape). The changes of form which certain animals undergo in passing from their younger to their fully-grown condition.

METAPODIUM (Gr. *meta*, after; *pous*, the foot). The posterior lobe of the foot in *Mollusca;* often called the "operculigerous lobe," because it develops the operculum when this structure is present.

METASTOMA (Gr. *meta*, after; *stoma*, mouth). The plate which closes the mouth posteriorly in the *Crustacea*.

METATARSUS (Gr. *meta*, after; *tarsos*, the instep). The bones which intervene between the bones of the ankle (*tarsus*) and the digits in the hind-foot of the higher Vertebrates.

METATHORAX (Gr. *meta*, after; *thorax*, the chest). The posterior ring of the thorax in Insects.

METAZOA (Gr. *meta*, implying change; *zoön*, animal). Applied to animals in which the primitive indifferent tissue of the embryo becomes converted into cells, which in turn may or may not be developed into more complex tissues. Under this head are included all animals except the *Protozoa*.

MIMETIC (Gr. *mimetikos*, imitative). Applied to organs or animals which resemble each other in external appearance, but not in essential structure.

MOLARS (Lat. *mola*, a mill). The "grinders" in man, or the teeth in diphyodont Mammals which are not preceded by milk-teeth.

MOLLUSCA (Lat. *mollis*, soft). The sub-kingdom which includes the shell-fish proper, the *Polyzoa*, the *Tunicata*, and the Lamp-shells; so called from the generally soft nature of their bodies.

MOLLUSCOIDA (*Mollusca;* Gr. *eidos*, form). The lower division of the *Mollusca*, comprising the *Polyzoa*, *Tunicata*, and *Brachiopoda*.

MONADS (Gr. *monas*, unity). Microscopical organisms of an extremely simple character, developed in organic infusions.

MONERA (Gr. *monēres*, single). An order of Protozoa, comprising animals composed of simple undifferentiated sarcode.

MONOCULOUS. Possessed of only one eye.

MONODELPHIA (Gr. *monos*, single; *delphus*, womb). The division of *Mammalia* in which the uterus is single.

MONŒCIOUS (Gr. *monos*, single; *oikos*, house). Applied to individuals in which the sexes are united.

MONOMYARY (Gr. *monos*, single; *muon*, muscle). Applied to those bivalves

(*Lamellibranchiata*) in which the shell is closed by a single adductor muscle.

MONOPHYODONT (Gr. *monos ; phuo*, I generate ; *odous*, tooth). Applied to those Mammals in which only a single set of teeth is ever developed.

MONOTHALAMOUS (Gr. *monos ;* and *thalamos*, chamber). Possessing only a single chamber. Applied to the shells of *Foraminifera* and *Mollusca.*

MONOTREMATA (Gr. *monos ; trema*, aperture). The order of Mammals comprising the Duck-mole and *Echidna*, in which the intestinal canal opens into a "cloaca" common to the ducts of the urinary and generative organs.

MULTILOCULAR (Lat. *multus*, many ; *loculus*, a little purse). Divided into many chambers.

MULTIVALVE. Applied to shells which are composed of many pieces.

MULTUNGULA (Lat. *multus*, many ; *ungula*, hoof). The division of Perissodactyle Ungulates, in which each foot has more than a single hoof.

MYELON (Gr. *muelos*, marrow). The spinal cord of Vertebrates.

MYRIAPODA or MYRIOPODA (Gr. *murios*, ten thousand ; *podes*, feet). A class of *Arthropoda* comprising the Centipedes and their allies, characterised by their numerous feet.

NACREOUS (Fr. *nacre*, mother-of-pearl, originally Oriental). Pearly ; of the texture of mother-of-pearl.

NATATORES (Lat. *nare*, to swim). The order of the Swimming Birds.

NATATORY (Lat. *nare*, to swim). Formed for swimming.

NAUTILOID. Resembling the shell of the *Nautilus* in shape.

NECTOCALYX (Gr. *necho*, I swim ; *kalux*, cup). The swimming-bell or "disc" of a *Medusa* or Jelly-fish.

NEMATELMIA (Gr. *nema*, thread ; *helmins*, a worm). The division of *Scolecida* comprising the Round-worms, Thread-worms, &c.

NEMATOCYSTS (Gr. *nema*, thread ; *kustis*, a bag). The thread-cells of the *Cœlenterata.* (*See* Cnidæ.)

NEMATOIDEA (Gr. *nema*, thread ; *eidos*, form). An order of *Scolecida* comprising the Thread-worms, Vinegar-eels, &c.

NEMATOPHORES (Gr. *nema*, thread ; *phero*, I carry). Cæcal processes found on the cœnosarc of certain of the *Sertularida*, containing numerous thread-cells at their extremities.

NEMERTIDA (Gr. *Nemertes*, proper name). A division of the *Turbellarian Worms*, commonly called "Ribbon-worms."

NERVURES (Lat. *nervus*, a sinew). The ribs which support the membranous wings of insects.

NEURAL (Gr. *neuron*, a nerve). Connected with the nervous system.

NEURAPOPHYSIS (Gr. *neuron*, a nerve ; *apophusis*, a projecting part). The "spinous process" of a vertebra, or the process formed at the point of junction of the neural arches.

NEUROPODIUM (Gr. *neuron*, a nerve ; *pous*, the foot). The ventral or inferior division of the "foot-tubercle" of an *Annelide ;* often called the "ventral oar."

NEUROPTERA (Gr. *neuron ;* and *pteron*, a wing). An order of insects characterised by four membranous wings with numerous reticulated nervures (*e.g.*, Dragon-flies).

NEUTER (Lat. neither the one nor the other). Having no fully developed sex.

NIDIFICATION (Lat. *nidus*, a nest ; *facio*, I make). The building of a nest.

NOCTURNAL (Lat. *nox*, night). Applied to animals which are active by night.

NORMAL (Lat. *norma*, a rule). Conforming to the ordinary standard.

NOTOBRANCHIATA (Gr. *notos*, the back ; and *bragchia*, gill). Carrying the gills upon the back ; applied to a division of the *Annelida.*

NOTOCHORD (Gr. *notos*, the back ; *chorde*, string). A cellular rod which is developed in the embryo of Vertebrates immediately beneath the spinal cord, and which is usually replaced in the adult by the vertebral column. Often it is spoken of as the "chorda dorsalis."

NOTOPODIUM (Gr. *notos*, the back ; and *pous*, the foot). The dorsal division of one of the foot-tubercles or parapodia of an *Annelide ;* often called the "dorsal oar."

NUCLEATED. Possessing a nucleus or central particle.

NUCLEOLUS. 1. The minute solid particle in the interior of the nucleus of some cells. 2. The minute spherical particle attached to the exterior of the "nucleus" or ovary of certain *Infusoria*, performing the functions of a testicle.

NUCLEUS (Lat. *nucleus*, a kernel). 1. The solid or vesicular body found in many cells. 2. The solid rod, or band-shaped body found in the interior of many of the *Protozoa*, and having, in certain of them, the functions of an ovary. 3. The "madreporiform tubercle" of the *Echinodermata*. 4. The embryonic shell which is retained to form the apex of the adult shell in many of the *Mollusca*.

NUDIBRANCHIATA (Lat. *nudus*, naked; and Gr. *bragchia*, gill). An order of the *Gasteropoda* in which the gills are naked.

NYMPHS. The active pupæ of certain Insects.

OCCIPITAL. Connected with the *occiput* or the back part of the head.

OCEANIC. Applied to animals which inhabit the open ocean (=pelagic).

OCELLI (Lat. diminutive of *oculus*, eye). The simple eyes of many Echinoderms, Spiders, Crustaceans, Molluscs, &c.

OCTOPODA (Gr. *octo*, eight; *pous*, foot). The tribe of Cuttle-fishes with eight arms attached to the head.

ODONTOCETI (Gr. *odous*, tooth; *ketos*, whale). The "toothed" Whales, in contradistinction to the "whalebone" Whales.

ODONTOID (Gr. *odous; eidos*, form.) The "odontoid process" is the centrum or body of the first cervical vertebra (*atlas*). It is detached from the atlas, and is usually anchylosed with the second cervical vertebra (*axis*), and it forms the pivot upon which the head rotates.

ODONTOPHORE (Gr. *odous*, tooth; *phero*, I carry). The so-called "tongue" or masticatory apparatus of *Gasteropoda*, *Pteropoda*, and *Cephalopoda*.

ODONTOPTERYX (Gr. *odous*, tooth; *pterux*, wing). An extinct genus of Birds.

ODONTORNITHES (Gr. *odous*, tooth; *ornis*, bird). The extinct sub-class of Birds comprising forms with distinct teeth in sockets.

ŒSOPHAGUS. The gullet or tube leading from the mouth to the stomach.

OLIGOCHÆTA (Gr. *oligos*, few; *chaite*, hair). An order of *Annelida*, comprising the Earth-worms, in which there are few bristles.

OMASUM (Lat. bullock's-tripe). The third stomach of Ruminants, commonly called the *psalterium*, or many-plies.

OMNIVOROUS (Lat. *omnia*, everything; *voro*, I devour). Feeding indiscriminately upon all sorts of food.

ONYCHOPHORA (Gr. *onux*, claw or nail; *phero*, I carry). The order of which *Peripatus*, with its hooked feet, is the type.

OOCYSTS (Gr. *oön*, egg; *kustis*, bladder). Chambers appended to the cells of certain of the Polyzoa, which serve as a receptacle for the eggs. Sometimes called "ovicells."

OPERCULATA (Lat. *operculum*, a lid). A division of pulmonate *Gasteropoda*, in which the shell is closed by an operculum.

OPERCULUM. A horny or shelly plate developed, in certain *Mollusca*, upon the hinder part of the foot, and serving to close the aperture of the shell when the animal is retracted within it; also the lid of the shell of a *Balanus* or Acorn-shell; also the chain of flat bones which covers the gills in many fishes.

OPHIDIA (Gr. *ophis*, a serpent). The order of Reptiles comprising the Snakes.

OPHIDOBATRACHIA (Gr. *ophis; batrachos*, a frog). Sometimes applied to the order of Snake-like Amphibians comprising the *Cæciliæ*.

OPHIOMORPHA (Gr. *ophis; morphe*, shape). The order of *Amphibia* comprising the *Cæciliæ*.

OPHIUROIDEA (Gr. *ophis*, snake; *oura*, tail; *eidos*, form). An order of *Echinodermata* comprising the Brittle-stars and Sand-stars.

OPISTHOBRANCHIATA (Gr. *opisthen*, behind; *bragchia*, gill). A division of *Gasteropoda*, in which the gills are placed on the posterior part of the body.

OPISTHOCŒLOUS (Gr. *opisthen*, behind; *koilos*, hollow). Applied to vertebræ the bodies of which are hollow or concave behind.

Oral (Lat. *os*, mouth). Connected with the mouth.

Ornithodelphia (Gr. *ornis*, a bird; *delphus*, womb). The primary division of Mammals comprising the *Monotremata*.

Ornithoscelida (Gr. *ornis*, bird; *skelos*, leg). Applied by Huxley to the Deinosaurian Reptiles, together with the genus *Compsognathus*, on account of the bird-like characters of their hind-limbs.

Orthoceratidæ (Gr. *orthos*, straight; *keras*, horn). A family of the *Nautilidæ*, in which the shell is straight, or nearly so.

Orthoptera (Gr. *orthos*, straight; *pteron*, wing). An order of Insects.

Oscula (Lat. diminutive of *os*, mouth). 1. The large apertures by which a sponge is perforated ("exhalant apertures"). 2. The suckers with which the *Tæniada* (Tape-worms and Cystic Worms) are provided.

Ossicula (Lat. diminutive of *os*, bone). Literally small bones. Often used to designate any hard structures of small size, such as the calcareous plates in the integument of the Star-fishes.

Ostracoda (Gr. *ostrakon*, a shell). An order of small Crustaceans which are enclosed in bivalve shells.

Otoliths (Gr. *ous*, ear; and *lithos*, stone). The calcareous bodies connected with the sense of hearing, even in its most rudimentary form.

Ovarian Vesicles or Capsules. The generative buds of the *Sertularida*.

Ovary (Ovarium). The organ by which ova are produced.

Oviparous (Lat. *ovum*, an egg; and *pario*, I bring forth). Applied to animals which bring forth eggs, in contradistinction to those which bring forth their young alive.

Ovipositor (Lat. *ovum;* and *pono*, I place). The organ possessed by some insects, by means of which the eggs are placed in a position suitable for their development.

Ovisac. The external bag or sac in which certain of the Invertebrates carry their eggs after they are extruded from the body.

Ovoviviparous (Lat. *ovum*, egg; *vivus*, alive; *pario*, I produce). Applied to animals which retain their eggs within the body until they are hatched.

Ovum (Lat. an egg). The germ produced within the ovary, and capable under certain conditions of being developed into a new individual.

Pachydermata (Gr. *pachus*, thick; *derma*, skin). An old Mammalian order constituted by Cuvier for the reception of the Rhinoceros, Hippopotamus, Elephant, &c.

Palæontology (Gr. *palaios*, ancient; *onta*, beings; and *logos*, discourse). The science of fossil remains or of extinct organised beings.

Palæozoic (Gr. *palaios*, ancient; and *zoe*, life). Applied to the oldest of the great geological epochs.

Palliobranchiata (Lat. *pallium*, a cloak; and Gr. *bragchia*, gill). An old name for the *Brachiopoda*, founded upon the belief that the system of tubes in the mantle constituted the gills.

Pallium (Lat. a cloak). The mantle of the *Mollusca*. *Pallial;* relating to the mantle. *Pallial line* or *impression;* the line left in the dead shell by the muscular margin of the mantle. *Pallial shell;* a shell which is secreted by, or contained within, the mantle, such as the "bone" of the Cuttle-fishes.

Palpi (Lat. *palpo*, I touch). Processes supposed to be organs of touch, developed from certain of the oral appendages in Insects, Spiders, and Crustacea, and from the sides of the mouth in the Acephalous Molluscs.

Panspermy (Gr. *pan*, all; *sperma*, seed). The theory that living beings are never produced except from pre-existent living beings.

Papilla (Lat. for nipple). A minute soft prominence.

Parapodia (Gr. *para*, beside; *podes*, feet). The unarticulated lateral locomotive processes or "foot-tubercles" of many of the *Annelida*.

Parietal (Lat. *paries*, a wall). Connected with the walls of a cavity or of the body.

Parietosplanchnic (Lat. *paries;* Gr. *splagchna*, viscera). Applied to one of the nervous ganglia of the *Mollusca*, which supplies the walls of the body and the viscera.

PARTHENOGENESIS (Lat. *parthenos*, a virgin; and *gignomai*, to be born). Strictly speaking, confined to the production of new individuals from virgin females by means of ova without the intervention of a male. Sometimes used also to designate asexual reproduction by gemmation or fission.

PATAGIUM (Lat. the border of a dress). Applied to the expansion of the integument by which Bats, Flying Squirrels, and other animals support themselves in the air.

PATELLA. The knee-cap or knee-pan. A sesamoid bone developed in the tendon of insertion of the great extensor muscles of the thigh.

PAUROPODA (Gr. *pauros*, little; *podes*, feet). An order of *Myriapoda*.

PECTINATE (Lat. *pecten*, a comb). Comb-like; applied to the gills of certain *Gasteropods*, hence called *Pectinibranchiata*.

PECTORAL (Lat. *pectus*, chest). Connected with, or placed upon, the chest.

PERENNIBRANCHIATA (Lat. *perennis*, perpetual; Gr. *bragchia*, gill). Applied to those *Amphibia* in which the gills are permanently retained throughout life.

PEDAL (Lat. *pes*, the foot). Connected with the foot of the *Mollusca*.

PEDICELLARIÆ (Lat. *pedicellus*, a louse). Certain singular appendages found in many *Echinoderms*, attached to the surface of the body, and resembling a little beak or forceps supported on a stalk.

PEDICLE (Lat. dim. of *pes*, the foot). A little stem.

PEDIPALPI (Lat. *pes*, foot; and *palpo*, I feel). An order of *Arachnida* comprising the Scorpions, &c.

PEDUNCLE (Lat. *pedunculus*, a stem or stalk). In a restricted sense applied to the muscular process by which certain *Brachiopods* are attached, and to the stem which bears the body (capitulum) in Barnacles.

PEDUNCULATE. Possessing a peduncle.

PELAGIC (Gr. *pelagos*, sea). Inhabiting the open ocean.

PELECYPODA (Gr. *pelekus*, an axe; *podes*, feet). A name often applied to the *Lamellibranchiata*, on account of many of them having a hatchet-shaped or sickle-shaped foot.

PELVIS (Lat. for basin). Applied, from analogy, to the basal portion of the cup (*calyx*) of *Crinoids*. The bony arch with which the hind-limbs are connected in Vertebrates.

PERGAMENTACEOUS (Lat. *pergamena*, parchment). Of the texture of parchment.

PERICARDIUM (Gr. *peri*, around; *kardia*, heart). The serous membrane in which the heart is contained.

PERIDERM (Gr. *peri*, around; and *derma*, skin). The hard cuticular layer which is developed by the cœnosarc of certain of the *Hydrozoa*.

PERIGASTRIC (Gr. *peri*, around; and *gaster*, stomach). The perigastric space is the cavity which surrounds the stomach and other viscera, corresponding to the abdominal cavity of the higher animals.

PERIOSTRACUM (Gr. *peri*; and *ostrakon*, shell). The layer of epidermis which covers the shell in most of the *Mollusca*.

PERIPLAST (Gr. *peri*; and *plasso*, I mould). The intercellular substance or matrix in which the organised structures of a tissue are embedded.

PERISARC (Gr. *peri*, around; *sarx*, flesh). Employed by Prof. Allman as a general term for the chitinous envelope secreted by many of the *Hydrozoa*.

PERISOME (Gr. *peri*; and *soma*, body). The coriaceous or calcareous integument of the *Echinodermata*.

PERISSODACTYLA (Gr. *perissos*, uneven; *daktulos*, finger). Applied to those Hoofed Quadrupeds (*Ungulata*) in which the feet have an uneven number of toes.

PERISTOME (Gr. *peri*; and *stoma*, mouth). The space which intervenes between the mouth and the margin of the calyx in *Vorticella*; also the space between the mouth and the tentacles in a sea-anemone (*Actinia*); also the lip or margin of the mouth of a univalve shell.

PERIVISCERAL (Gr. *peri*; and Lat. *viscera*, the internal organs). Applied to the space surrounding the viscera.

PETALOID. Shaped like the petals of a flower.

PHALANGES (Gr. *phalanx*, a row). The small bones composing the digits of the higher *Vertebrata*. Normally each digit has three phalanges.

PHARYNGOBRANCHII (Gr. *pharugx*, pharynx; *bragchia*, gill). The order of Fishes comprising only the Lancelet.

PHARYNX. The dilated commencement of the gullet.

PHRAGMACONE (Gr. *phragma*, a partition; and *konos*, a cone). The chambered portion of the internal shell of a *Belemnite*.

PHYLACTOLÆMATA (Gr. *phulasso*, I guard; and *laimos*, throat). The division of *Polyzoa* in which the mouth is provided with the arched valvular process known as the "epistome."

PHYLLOCYSTS (Gr. *phullon*, leaf; and *kustis*, a cyst). The cavities in the interior of the "hydrophyllia" of certain of the Oceanic *Hydrozoa*.

PHYLLOPODA (Gr. *phullon*, leaf; and *pous*, foot). An order of *Crustacea*.

PHYOGEMMARIA (Gr. *phuo*, I produce; and Lat. *gemma*, bud). The small gonoblastidia of *Velella*, one of the *Physophoridæ*.

PHYSOGRADA (Gr. *phusa*, bellows or air-bladder; and Lat. *gradior*, I walk). Applied formerly to the *Physophoridæ*, an order of Oceanic *Hydrozoa*, in which a "float" is present.

PHYSOPHORIDÆ (Gr. *phusa*, air-bladder; and *phero*, I carry). An order of Oceanic *Hydrozoa*.

PHYTOID (Gr. *phuton*, a plant; and *eidos*, form). Plant-like.

PHYTOPHAGOUS (Gr. *phuton*, a plant; and *phago*, I eat). Plant-eating, or herbivorous.

PINNATE (Lat. *pinna*, a feather). Feather-shaped, or possessing lateral processes.

PINNIGRADA (Lat. *pinna*, a feather; *gradior*, I walk). The group of *Carnivora*, comprising the Seals and Walruses, adapted for an aquatic life. Often called *Pinnipedia*.

PINNULÆ (Lat. dim. of *pinna*). The lateral processes of the arms of *Crinoids*.

PISCES (Lat. *piscis*, a fish). The class of Vertebrates comprising the Fishes.

PLACENTA (Lat. a cake). The "after-birth," or the organ by which a vascular connection is established in the higher *Mammalia* between the mother and the fœtus.

PLACENTAL. Possessing a placenta, or connected with the placenta.

PLACOID (Gr. *plax*, a plate; *eidos*, form). Applied to the irregular bony plates, grains, or spines which are found in the skin of various fishes (*Elasmobranchii*).

PLAGIOSTOMI (Gr. *plagios*, transverse; *stoma*, mouth). The Sharks and Rays, in which the mouth is transverse, and is placed on the under surface of the head.

PLANARIDA (Gr. *planē*, wandering). A sub-order of the *Turbellaria*.

PLANTIGRADE (Lat. *planta*, the sole of the foot; *gradior*, I walk). Applying the sole of the foot to the ground in walking.

PLANULA (Lat. *planus*, flat). The oval ciliated embryo of certain of the Invertebrates.

PLASTRON. The lower or ventral portion of the bony case of the Chelonians.

PLATYELMIA (Gr. *platus*, broad; and *helmins*, an intestinal worm). The division of *Scolecida* comprising the Tape-worms, &c.

PLATYRHINA (Gr. *platus*, broad; *rhines*, nostrils). The group of the *Quadrumana*.

PLEURA (Gr. the side). The serous membrane covering the lung in the air-breathing Vertebrates.

PLEURON (Gr. *pleuron*, a rib). The lateral extensions of the shell of *Crustacea*.

PLUTEUS (Lat. a pent-house). The larval form of the *Echinoidea*.

PNEUMATIC (Gr. *pneuma*, air) Filled with air.

PNEUMATOCYST (Gr. *pneuma*, air; and *kustis*, cyst). The air-sac or float of certain of the Oceanic *Hydrozoa* (*Physophoridæ*).

PNEUMATOPHORE (Gr. *pneuma*, air; and *phero*, I carry). The proximal dilatation of the cœnosarc in the *Physophoridæ* which surrounds the pneumatocyst.

PNEUMOSKELETON (Gr. *pneuma*; and *skeletos*, dry). The hard structures which are connected with the breathing organs (*e.g.*, the shell of Molluscs).

PODOPHTHALMATA (Gr. *pous*, foot; and *ophthalmos*, eye). The division of Crustacea in which the eyes are borne at the end of long foot-stalks.

PODOSOMATA (Gr. *pous*, foot; *soma*, body). An order of *Arachnida.*

POEPHAGA (Gr. *poē*, grass, *phago*, I eat). A group of the Marsupials.

POLLEX (Lat. the thumb). The innermost of the five normal digits of the anterior limb of the higher Vertebrates. In man, the thumb.

POLYCHÆTA (Gr. *polus*, many; *chaite*, bristle). A name often applied to the Tubicolar and Errant Annelides to distinguish them collectively from the *Oligochæta* (Earthworms, &c.).

POLYCYSTINA (Gr. *polus*, many; and *kustis*, a cyst). An order of *Protoza*, with foraminated siliceous shells.

POLYGASTRICA (Gr. *polus;* and *gaster*, stomach). The name applied by Ehrenberg to the *Infusoria*, under the belief that they possessed many stomachs.

POLYPARY. The hard chitinous covering secreted by many of the *Hydrozoa.*

POLYPE (Gr. *polus*, many; *pous*, foot). Restricted to the single individual of a simple *Actinozoön*, such as a Sea-anemone, or to the separate zoöids of a compound *Actinozoön.* Often applied indiscriminately to any of the *Cœlenterata*, or even to the *Polyzoa.*

POLYPIDE. The separate zoöid of a *Polyzoön.*

POLYPIDOM. The dermal system of a colony of a *Hydrozoön* or *Polyzoon.*

POLYPITE. The separate zoöid of a *Hydrozoön.*

POLYSTOME (Gr. *polus*, many; and *stoma*, mouth). Having many mouths; applied to the *Acinetæ* amongst the *Protozoa.*

POLYTHALAMOUS (Gr. *polus;* and *thalamos*, chamber). Having many chambers; applied to the shells of *Foraminifera* and *Cephalopoda.*

POLYTROCHAL (Gr. *polus*, many; *trochos*, wheel). An epithet applied to those larvæ of Annelides and other Invertebrates, in which there are successively-disposed circlets of cilia.

POLYZOA (Gr. *polus;* and *zoön*, animal). A division of the *Molluscoida*, comprising compound animals, such as the Sea-mat. Sometimes called *Bryozoa.*

POLYZOARIUM. The dermal system of the colony of a *Polyzoön* (= Polypidom).

PORCELLANOUS. Of the texture of porcelain.

PORIFERA (Lat. *porus*, a pore; and *fero*, I carry). Sometimes used to designate the *Foraminifera*, or the *Sponges.*

POST-ABDOMEN. That portion of the "abdomen" of *Crustacea, Arachnida*, and *Myriapoda* which lies behind the segments corresponding with the abdomen of Insects.

POST-ANAL. Situated behind the anus.

POST-ŒSOPHAGEAL. Situated behind the gullet.

POST-ORAL. Situated behind the mouth.

PRÆ-MAXILLÆ. (*See* Intermaxillæ.)

PRÆMOLARS (Lat. *præ*, before; *molares*, the grinders). The molar teeth of Mammals which succeed the molars of the milk-set of teeth. In man, the bicuspid teeth.

PRÆ-ŒSOPHAGEAL. Situated in front of the gullet.

PRÆ-STERNUM. The anterior portion of the breast-bone, corresponding with the *manubrium sterni* of human anatomy, and extending as far as the point of articulation of the second rib.

PRESSIROSTRES (Lat. *pressus*, compressed; *rostrum*, beak). A group of the Grallatorial Birds.

PROBOSCIDEA (Lat. *proboscis*, the snout). The order of Mammals comprising the Elephants.

PROBOSCIS (Lat. or Gr. the snout). Applied to the spiral trunk of *Lepidopterous Insects*, to the projecting mouth of certain *Crinoids*, and to the central polypite in the *Medusæ.*

PROCŒLOUS (Gr. *pro*, before; *koilos*, hollow). Applied to vertebræ, the bodies of which are hollow or concave in front.

PROGLOTTIS (Gr. for the tip of the tongue). The generative segment or joint of a Tape-worm.

PRO-LEGS. The false abdominal feet of Caterpillars.

PRONATION (Lat. *pronus*, lying on the face, prone). The act of turning the palm of the hand downwards.

Propodium (Gr. *pro,* before; *pous,* foot). The anterior part of the foot in Molluses.

Proscolex (Gr. *pro,* before; *scolex,* worm). The first embryonic stage of a Tape-worm.

Prosobranchiata (Gr. *proson,* in advance of; *bragchia,* a gill). A division of Gasteropodous Molluscs in which the gills are situated in advance of the heart.

Prosoma (Gr. *pro,* before; *soma,* body). The anterior part of the body.

Prothorax (Gr. *pro;* and *thorax,* chest). The anterior ring of the thorax of insects.

Protophyta (Gr. *protos,* first; and *phuton,* plant). The lowest division of plants.

Protoplasm (Gr. *protos;* and *plasso,* I mould). The elementary basis of organised tissues. Used synonymously with the "sarcode" of the *Protozoa.*

Protopodite (Gr. *protos,* first; and *pous,* foot). The basal segment of the typical limb of a *Crustacean.*

Protozoa (Gr. *protos;* and *zoön,* animal). The lowest division of the animal kingdom.

Proventriculus (Lat. *pro,* in front of; *ventriculus,* dim. of *venter,* belly). The cardiac portion of the stomach of birds.

Proximal (Lat. *proximus,* next). The slowly-growing, comparatively-fixed extremity of a limb or of an organism.

Psalterium (Lat. a stringed instrument). The third stomach of Ruminants. (*See* Omasum.)

Pseudembryo (Gr. *pseudos,* falsity; *embruon,* embryo). The larval form of an *Echinoderm.*

Pseudobranchia (Gr. *pseudos,* falsity; *bragchia,* gill). A supplementary gill found in certain fishes, which receives arterialised blood only, and does not, therefore, assist in respiration.

Pseudohæmal (Gr. *pseudos,* falsity; and *haima,* blood). Applied to the vascular system of *Annelida.*

Pseudo-hearts. Certain contractile cavities connected with the atrial system of *Brachiopoda,* and long considered to be hearts.

Pseudo-navicellæ (Gr. *pseudos,* false; and *Navicula,* a genus of Diatoms). The embryonic forms of the *Gregarinidæ,* so called from their resemblance in shape to the *Navicula.*

Pseudopodia (Gr. *pseudos;* and *pous,* foot). The extensions of the body-substance which are put forth by the *Rhizopoda* at will, and which serve for locomotion and prehension.

Pseudova (Gr. *pseudos;* Lat. *ovum,* egg). The egg-like bodies from which the young of the viviparous *Aphis* are produced.

Pteropoda (Gr. *pteron,* wing; and *pous,* foot). A class of the *Mollusca* which swim by means of fins attached near the head.

Pterosauria (Gr. *pteron,* wing; *saura,* lizard). An extinct order of reptiles.

Pubis (Lat. *pubes,* hair). The share-bone; one of the bones which enter into the composition of the pelvic arch of Vertebrates.

Pulmogasteropoda (=Pulmonifera).

Pulmonaria. A division of *Arachnida* which breathe by means of pulmonary sacs.

Pulmonate. Possessing lungs.

Pulmonifera (Lat. *pulmo,* a lung; and *fero,* I carry). The division of *Mollusca* which breathe by means of a pulmonary chamber.

Pupa (Lat. a doll). The stage of an insect immediately preceding its appearance in a perfect condition. In the pupa-stage it is usually quiescent—when it is often called a "chrysalis;" but it is sometimes active—when it is often called a "nymph."

Pylorus (Gr. *puloros,* a gatekeeper). The valvular aperture between the stomach and the intestine.

Pyriform (Lat. *pyrus,* a pear; and *forma,* form). Pear-shaped.

Quadrumana (Lat. *quatuor,* four; *manus,* hand). The order of Mammals comprising the Apes, Monkeys, Baboons, Lemurs, &c.

RADIATA (Lat. *radius*, a ray). Formerly applied to a large number of animals which are now placed in separate sub-kingdoms (*e.g.*, the *Cœlenterata*, the *Echinodermata*, the *Infusoria*, &c.).

RADIOLARIA (Lat. *radius*, a ray). A division of *Protozoa*.

RADIUS (Lat. a spoke or ray). The innermost of the two bones of the fore-arm of the higher Vertebrates. It carries the thumb, when present, and corresponds with the tibia of the hind-limb.

RADULA (Lat. *radula*, a scraping-iron). An epithet often given to the toothed lingual ribbon or "odontophore" of the higher Mollusca.

RAMUS (Lat. a branch). Applied to each half or branch of the lower jaw or mandible of Vertebrates.

RAPTORES (Lat. *rapto*, I plunder). The order of the Birds of Prey.

RASORES (Lat. *rado*, I scratch). The order of the Scratching Birds (Fowls, Pigeons, &c.).

RATITÆ (Lat. *rates*, a raft). Applied by Huxley to the Cursorial Birds, which do not fly, and have therefore a raft-like sternum without any median keel.

RECTUM (Lat. *rectus*, straight). The terminal portion of the intestinal canal, opening at the surface of the body at the anus.

REPTILIA (Lat. *repto*, I crawl). The class of the *Vertebrata* comprising the Tortoises, Snakes, Lizards, Crocodiles, &c.

RETICULOSA (Lat. *reticulum*, a net). Employed by Dr Carpenter to designate those *Protozoa*, such as the *Foraminifera*, in which the pseudopodia run into one another and form a network.

RETICULUM (Lat. a net). The second division of the complex stomach of Ruminants, often called the "honeycomb-bag."

REVERSED. Applied to spiral univalves, in which the direction of the spiral is the reverse of the normal—*i.e.*, *sinistral*.

RHABDOPHORA (Gr. *rhabdos*, a rod; and *phero*, I carry). Employed by Prof. Allman as a name for the Graptolites, in consequence of their commonly possessing a chitinous rod or axis supporting the perisarc.

RHIZOPHAGA (Gr. *rhiza*, root; *phago*, I eat). A group of the Marsupials.

RHIZOPODA (Gr. *rhiza*, a root; and *pous*, foot). The division of *Protozoa* comprising all those which are capable of emitting pseudopodia.

RHOPALOCERA (Gr. *rhopalon*, club; *keras*, horn). A name given to the Butterflies among the Lepidoptera in allusion to the fact that the antennæ are clubbed at the end.

RHYNCHOLITES (Gr. *rhunchos*, beak; and *lithos*, stone). Beak-shaped fossils, consisting of the mandibles of *Cephalopoda*.

RODENTIA (Lat. *rodo*, I gnaw). An order of the Mammals; often called *Glires* (Lat. *glis*, a dormouse).

ROSTRUM (Lat. *rostrum*, beak). The "beak" or suctorial organ formed by the appendages of the mouth in certain insects.

ROTATORIA (=Rotifera).

ROTIFERA (Lat. *rota*, wheel; and *fero*, I carry). A class of the *Scolecida* (*Annuloida*) characterised by a ciliated "trochal disc."

RUGOSA (Lat. *rugosus*, wrinkled). An order of Corals.

RUMEN (Lat. the throat). The first cavity of the complex stomach of Ruminants; often called the "paunch."

RUMINANTIA (Lat. *ruminor*, I chew the cud). The group of Hoofed Quadrupeds (*Ungulata*) which "ruminate" or chew the cud.

SACRUM. The vertebræ (usually anchylosed) which unite with the haunch-bones (*ilia*) to form the pelvis.

SAND-CANAL (=STONE-CANAL). The tube by which water is conveyed from the exterior to the ambulacral system of the *Echinodermata*.

SARCODE (Gr. *sarx*, flesh; *eidos*, form). The jelly-like substance of which the bodies of the *Protozoa* are composed. It is an albuminous body containing oil-granules, and is identical with protoplasm.

SARCOIDS (Gr. *sarx;* and *eidos*, form). The separate amœbiform particles which in the aggregate make up the "flesh" of a Sponge.

SAURIA (Gr. *saura*, a lizard). Any lizard-like Reptile is often spoken of as a

"Saurian;" but the term is sometimes restricted to the Crocodiles alone, or to the Crocodiles and Lacertilians.

SAUROBATRACHIA (Gr. *saura; batrachos*, frog). Sometimes applied to the order of the tailed Amphibians (*Urodela*).

SAUROPSIDA (Gr. *saura;* and *opsis*, appearance). The name given by Huxley to the two classes of the Birds and Reptiles collectively.

SAUROPTERYGIA (Gr. *saura; pterux*, wing). An extinct order of Reptiles. called by Huxley *Plesiosauria*, from the typical genus *Plesiosaurus*.

SAURURÆ (Gr. *saura; oura*, tail). The extinct order of Birds comprising only the *Archæopteryx*.

SCANSORES (Lat. *scando*, I climb). The order of the Climbing Birds (Parrots, Woodpeckers, &c.).

SCAPHOGNATHITE (Gr. *skaphos*, boat; and *gnathos*, jaw). The boat-shaped appendage (epipodite) of the second pair of maxillæ in the Lobster, the function of which is to spoon out the water from the branchial chamber.

SCAPULA (Lat. for shoulder-blade). The shoulder-blade of the pectoral arch of Vertebrates; in a restricted sense, the row of plates in the cup of *Crinoids*, which give origin to the arms, and are usually called the "axillary radials."

SCLERENCHYMA (Gr. *skleros*, hard; and *enchuma*, tissue). The calcareous tissue of which a coral is composed.

SCLERITES (Gr. *skleros*). The calcareous spicules which are scattered in the soft tissues of certain *Actinozoa*.

SCLEROBASIC (Gr. *skleros*, hard; *basis*, pedestal). Applied to the coral which is produced by the cœnosarc in certain *Actinozoa* (*e.g.*, Red Coral), and which forms a solid axis which is invested by the soft parts of the animal. It is called "foot-secretion" by Mr Dana.

SCLERODERMIC (Gr. *skleros;* and *derma*, skin). Applied to the corallum which is deposited between the tissues of certain *Actinozoa*, and is called "tissue-secretion" by Mr Dana.

SCLEROTIC (Gr. *skleros*, hard). The outer dense fibrous coat of the eye.

SCOLECIDA (Gr. *skolēx*, worm). A division of the *Annuloida*.

SCOLEX (Gr. *skolēx*). The embryonic stage of a Tape-worm, formerly known as a "Cystic worm."

SCUTA (Lat. *scutum*, a shield). Applied to any shield-like plates; especially to those which are developed in the integument of many Reptiles.

SELACHIA or SELACHII (Gr. *selachos*, a cartilaginous fish, probably a shark). The sub-order of *Elasmobranchii*, comprising the Sharks and Dog-fishes.

SEPIOSTAIRE. The internal shell of the *Sepia*, commonly known as the "cuttle-bone."

SEPTA. Partitions.

SERPENTIFORM. Resembling a serpent in shape.

SERTULARIDA (Lat. *sertum*, a wreath). An order of *Hydrozoa*.

SESSILE (Lat. *sedo*, I sit). Not supported upon a stalk or peduncle; attached by a base.

SETÆ (Lat. bristles). Bristles, or long stiff hairs.

SETIFEROUS. Supporting bristles.

SETIGEROUS (=Setiferous).

SETOSE. Bristly.

SILICEOUS (Lat. *silex*, flint). Composed of flint.

SINISTRAL (Lat. *sinistra*, the left hand). Left-handed; applied to the direction of the spiral in certain shells, which are said to be "reversed."

SINUS (Lat. *sinus*, a bay). A dilated vein or blood-receptacle.

SIPHON (Gr. *siphon*, a tube). Applied to the respiratory tubes in the *Mollusca;* also to other tubes of different functions.

SIPHONOPHORA (Gr. *siphon;* and *phero*, I carry). A division of the *Hydrozoa*, comprising the Oceanic forms (*Calycophoridæ* and *Physophoridæ*).

SIPHONOSTOMATA (Gr. *siphon;* and *stoma*, mouth). The division of *Gasteropodous Molluscs*, in which the aperture of the shell is not "entire," but possesses a notch or tube for the emission of the respiratory siphon.

SIPHUNCLE (Lat. *siphunculus*, a little tube). The tube which connects together the various chambers of the shell of certain *Cephalopoda* (*e.g.*, the Pearly Nautilus).

Sipunculoidea (Lat. *siphunculus*, a little siphon). A class of *Anarthropoda* (*Annulosa*).

Sirenia (Gr. *seiren*, a mermaid). The order of *Mammalia* comprising the Dugongs and Manatees.

Solidungula (Lat. *solidus*, solid; *ungula*, a hoof). The group of Hoofed Quadrupeds comprising the Horse, Ass, and Zebra, in which each foot, in the living forms, has only a single solid hoof. Often called *Solipedia.*

Somatic (Gr. *soma*, body). Connected with the body.

Somatocyst (Gr. *soma;* and *kustis*, a cyst). A peculiar cavity in the cœnosarc of the *Calycophoridæ* (*Hydrozoa*).

Somite (Gr. *soma*). A single segment in the body of an Articulate animal.

Spermarium. The organ in which spermatozoa are produced.

Spermatophores (Gr. *sperma*, seed; *phero*, I carry). The cylindrical capsules of the *Cephalopoda*, which carry the spermatozoa; sometimes called the "moving filaments of Needham."

Spermatozoa (Gr. *sperma*, seed; and *zoön*, animal). The microscopic filaments which form the essential generative element of the male.

Sphæridia (Gr. *sphairidion*, a little ball or sphere). Minute stalked appendages with button-shaped heads carried by most living Sea-urchins, and supposed to be organs of sense.

Spicula (Lat. *spiculum*, a point). Pointed needle-shaped bodies.

Spinnerets. The organs by means of which Spiders and Caterpillars spin threads.

Spiracles (Lat. *spiro*, I breathe). The breathing-pores, or apertures of the breathing-tubes (tracheæ) of Insects. Also the single nostril of the Hagfishes, the "blow-hole" of Cetaceans, &c.

Splanchnoskeleton (Gr. *splagchna*, viscera; *skeletos*, dry). The hard structures occasionally developed in connection with the internal organs or viscera.

Sponge-particles. (*See* Sarcoids.)

Spongida (Gr. *spoggos*, a sponge). The division of *Protozoa* commonly known as sponges.

Spores (Gr. *spora*, seed). Germs, usually of plants; in a restricted sense, the reproductive "gemmules" of certain sponges.

Sporosacs (Gr. *spora*, seed; and *sakkos*, a bag). The simple generative buds of certain *Hydrozoa*, in which the medusoid structure is not developed.

Squamata (Lat. *squama*, a scale). The division of reptiles comprising the *Ophidia* and *Lacertilia* in which the integument develops horny scales, but there are no dermal ossifications.

Statoblasts (Gr. *statos*, stationary; *blastos*, bud). Certain reproductive buds developed in the interior of *Polyzoa*, but not liberated until the death of the parent organism.

Steganophthalmata (Gr. *steganos*, covered; and *ophthalmos*, the eye). Applied by Edward Forbes to certain *Medusæ*, in which the sense-organs ("marginal bodies") are protected by a sort of hood. The *Steganophthalmata* are now separated from the true *Medusidæ*, and placed in a separate division under the name *Lucernarida*.

Stellerida (Lat. *stella*, star). Sometimes employed to designate the order of the Star-fishes.

Stelliform. Star-shaped.

Stemmata (Gr. *stemma*, garland). The simple eyes, or "ocelli," of certain animals, such as Insects, Spiders, and Crustacea.

Sternum (Gr. *sternon*). The breast-bone.

Stigmata. The breathing-pores in *Insects* and *Arachnida.*

Stolon (Gr. *stolos*, a sending forth). Offshoots.—The connecting processes of sarcode in *Foraminifera;* the connecting tube in the social *Ascidians;* the processes sent out by the cœnosarc of certain *Actinozoa.*

Stomapoda (Gr. *stoma*, mouth; *pous*, foot). An order of *Crustacea.*

Stomatode (Gr. *stoma*). Possessing a mouth. The *Infusoria* are thus often called the Stomatode *Protozoa.*

Strepsiptera (Gr. *strepho*, I twist; *pteron*, wing). An order of Insects in which the anterior wings are represented by twisted rudiments.

STREPSIRHINA (Gr. *strepho*, I twist; *rhines*, nostrils). A group of the Quadrumana, often spoken of as *Prosimiæ*.

STROBILA (Gr. *strobilos*, a top, or fir-cone). The adult Tape-worm, with its generative segments or proglottides; also applied to one of the stages in the life-history of the *Lucernarida*.

STYLIFORM (Lat. *stylus*, a pointed instrument; *forma*, form). Pointed in shape.

SUB-CALCAREOUS. Somewhat calcareous.

SUB-CENTRAL. Nearly central, but not quite.

SUB-PEDUNCULATE. Supported upon a very short stem.

SUB-SESSILE. Nearly sessile, or almost without a stalk.

SUPINATION (Lat. *supinus*, lying with the face upwards). The act of turning the hand with the palm upwards.

SUTURE (Lat. *suo*, I sew). The line of junction of two parts which are immovably connected together. Applied to the line where the whorls of a univalve shell join one another; also to the lines made upon the exterior of the shell of a chambered *Cephalopod* by the margins of the septa.

SWIMMERETS. The limbs of *Crustacea*, which are adapted for swimming.

SYMPHYSIS (Gr. *sumphusis*, a growing together). Union of two bones in which there is no motion, or but a very limited amount.

SYNAPTICULÆ (Gr. *sunapto*, I fasten together). Transverse props sometimes found in Corals, extending across the loculi like the bars of a grate.

SYSTOLÉ (Gr. *sustello*, I contract). Applied to the contraction of any contractile cavity, especially the heart.

TABULÆ (Lat. *tabula*, a tablet). Horizontal plates or floors found in some Corals, extending across the cavity of the "theca," from side to side.

TACTILE (Lat. *tango*, I touch). Connected with the sense of touch.

TÆNIADA (Gr. *tainia*, a ribbon). The division of *Scolecida* comprising the Tape-worms.

TÆNIOID (Gr. *tainia;* and *eidos*, form). Ribbon-shaped, like a Tape-worm.

TARSO-METATARSUS. The single bone in the leg of Birds produced by the union and anchylosis of the lower and distal portion of the tarsus with the whole of the metatarsus.

TARSUS (Gr. *tarsos*, the flat of the foot). The small bones which form the ankle (or "instep" of man), and which correspond with the wrist (*carpus*) of the anterior limb.

TECTIBRANCHIATA (Lat. *tectus*, covered; and Gr. *bragchia*, gills). A division of *Opisthobranchiate Gasteropoda* in which the gills are protected by the mantle.

TEGUMENTARY (Lat. *tegumentum*, a covering). Connected with the integument or skin.

TELEOSTEI (Gr. *teleios*, perfect; *osteon*, bone). The order of the "Bony" Fishes.

TELSON (Gr. a limit). The last joint in the abdomen of *Crustacea;* variously regarded as a segment without appendages, or as an azygous appendage.

TENUIROSTRES (Lat. *tenuis*, slender; *rostrum*, beak). A group of the Perching Birds characterised by their slender beaks.

TERGUM (Lat. for back). The dorsal arc of the somite of an Arthropod.

TERRICOLA (Lat. *terra*, earth; and *colo*, I inhabit). Employed occasionally to designate the Earth-worms (*Lumbricidæ*).

TEST (Lat. *testa*, shell). The shell of *Mollusca*, which are for this reason sometimes called "*Testacea;*" also, the calcareous case of *Echinoderms;* also, the thick leathery outer tunic in the *Tunicata*.

TESTACEOUS. Provided with a shell or hard covering.

TESTIS (Lat. *testis*, the testicle). The organ in the male animal which produces the generative fluid or semen.

TETRABRANCHIATA (Gr. *tetra*, four; *bragchia*, gill). The order of *Cephalopoda* characterised by the possession of four gills.

THALASSICOLLIDA (Gr. *thalassa*, sea; *kolla*, glue). A division of *Protozoa*.

THECA (Gr. *theke*, a sheath). A sheath or receptacle.

Thecosomata (Gr. *theke;* and *soma*, body). A division of *Pteropodous Molluscs*, in which the body is protected by an external shell.

Theriomorpha (Gr. *ther*, beast; *morphe*, shape). Applied by Owen to the order of the Tail-less Amphibians (*Anoura*).

Thorax (Gr. a breastplate). The chest.

Thread-cells. (*See* Cnidæ.)

Thysanura (Gr. *thusanoi*, fringes; and *oura*, tail). An order of Apterous Insects.

Tibia (Lat. a flute). The shin-bone, being the innermost of the two bones of the leg, and corresponding with the *radius* in the anterior extremity.

Totipalmatæ (Lat. *totus*, whole; *palma*, the palm of the hand). A group of Wading Birds in which the hallux is united to the other toes by membrane, so that the feet are completely webbed.

Toxodontia (Gr. *toxon*, bow; *odous*, tooth). A distinct order of Mammals.

Trachea (Gr. *tracheia*, the rough windpipe), The tube which conveys air to the lungs in the air-breathing Vertebrates.

Tracheæ. The breathing-tubes of Insects and other Articulate animals.

Trachearia. The division of *Arachnida* which breathe by means of tracheæ.

Trematoda (Gr. *trema*, a pore). An order of *Scolecida.*

Trichocysts (Gr. *thrix*, hair; and *kustis*, a cyst). Peculiar cells found in certain *Infusoria*, and very nearly identical with the "thread-cells" of *Cœlenterata.*

Trilobita (Gr. *treis*, three; *lobos*, a lobe). An extinct order of *Crustaceans.*

Tritozoöid (Gr. *tritos*, third; *zoön*, animal; and *eidos*, form). The zoöid produced by a deuterozoöid; that is to say, a zoöid of the third generation.

Trochal (Gr. *trochos*, a wheel). Wheel-shaped; applied to the ciliated disc of the *Rotifera.*

Trochanter (Gr. *trecho*, I turn). A process of the upper part of the thigh-bone (*femur*) to which are attached the muscles which rotate the limb. There may be two, or even three, trochanters present.

Trochoid (Gr. *trochos*, a wheel; and *eidos*, form). Conical with a flat base; applied to the shells of *Foraminifera* and *Univalve Molluscs.*

Trophi (Gr. *trophos*, a nourisher). The parts of the mouths in insects which are concerned in the acquisition and preparation of food. Often called "instrumenta cibaria."

Trophosome (Gr. *trepho*, I nourish; and *soma*, body). Applied collectively to the assemblage of the nutritive zoöids of any *Hydrozoön.*

Truncated (Lat. *trunco*, I shorten). Abruptly cut off; applied to univalve shells, the apex of which breaks off, so that the shell becomes "decollated."

Tubicola (Lat. *tuba*, a tube; and *colo*, I inhabit). The order of *Annelida* which construct a tubular case in which they protect themselves.

Tubicolous. Inhabiting a tube.

Tunicata (Lat. *tunica*, a cloak). A class of *Molluscoida* which are enveloped in a tough leathery case or "test."

Turbellaria (Lat. *turbo*, I disturb). An order of *Scolecida.*

Turbinated (Lat. *turbo*, a top). Top-shaped; conical with a round base.

Ulna (Gr. *olenê*, the elbow). The outermost of the two bones of the fore-arm, corresponding with the *fibula* of the hind-limb.

Umbellate (Lat. *umbella*, a parasol). Forming an umbel—*i.e.*, a number of nearly equal *radii* all proceeding from one point.

Umbilicus (Lat. for navel). The aperture seen at the base of the axis of certain univalve shells, which are then said to be "perforated" or "umbilicated."

Umbo (Lat. the boss of a shield). The beak of a bivalve shell.

Umbrella. The contractile disc of one of the *Lucernarida.*

Uncinate (Lat. *uncinus*, a hook). Provided with hooks or bent spines.

Unguiculate (Lat. *unguis*, nail). Furnished with claws.

Ungulata (Lat. *ungula*, hoof). The order of *Mammals* comprising the Hoofed Quadrupeds.

Ungulate. Furnished with expanded nails constituting hoofs.

UNILOCULAR (Lat. *unus*, one; and *loculus*, a little purse). Possessing a single cavity or chamber. Applied to the shells of *Foraminifera* and *Mollusca*.

UNIVALVE (Lat. *unus*, one; *valvæ*, folding doors). A shell composed of a single piece or valve.

URODELA (Gr. *oura*, tail; *delos*, visible). The order of the tailed Amphibians (Newts, &c.)

URTICATING CELLS (Lat. *urtica*, a nettle). (*See* Cnidæ).

VACUOLES (Lat. *vacuus*, empty). The little cavities formed in the interior of many of the *Protozoa* by the presence of little particles of food, usually surrounded by a little water. These are properly called "food vacuoles," and were supposed to be stomachs by Ehrenberg. Also the clear spaces which are often seen in the tissues of many *Cœlenterata*.

VARICES (Lat. *varix*, a dilated vein). The ridges or spinose lines which mark the former position of the mouth in certain univalve shells.

VASCULAR (Lat. *vas*, a vessel). Connected with the circulatory system.

VELIGER (Lat. *velum*, a sail; *gero*, I carry). A name applied to the larvæ of most of the Molluscs, on account of their possessing ciliated lappets forming a "velum."

VELUM (Lat. a sail). The membrane which surrounds and partially closes the mouth of the "disc" of *Medusæ* or of medusiform gonophores.

VENTRAL (Lat. *venter*, the stomach). Relating to the inferior surface of the body.

VENTRICLE (Lat. dim. of *venter*, stomach). Applied to one of the cavities of the heart, which receives blood from the auricle.

VERMES (Lat. *vermes*, a worm). Sometimes employed at the present day in the same, or very nearly the same, sense as *Annuloida*, or as *Annuloida* plus the *Anarthropoda*.

VERMIFORM (Lat. *vermis*, worm; and *forma*, form). Worm-like.

VERTEBRA (Lat. *verto*, I turn). One of the bony segments of the vertebral column or backbone.

VERTEBRATA (Lat. *vertebra*, a bone of the back, from *vertere*, to turn). The division of the Animal Kingdom roughly characterised by the possession of a backbone.

VESICLE (Lat. *vesica*, a bladder). A little sac or cyst.

VIBRACULA (Lat. *vibro*, I shake). Long filamentous appendages found in many *Polyzoa*.

VIBRIONES (Lat. *vibro*, I shake). The little moving filaments developed in organic infusions.

VIPERINA (Lat. *vipera*, a viper). A group of the Snakes.

VITREOUS (Lat. *vitrum*, glass). Glassy, transparent. The "vitreous" sponges are those with a skeleton of flint.

VIVIPAROUS (Lat. *vivus*, alive; and *pario*, I bring forth.) Bringing forth young alive.

WHORL. The spiral turn of a univalve shell.

XIPHISTERNUM (Gr. *xiphos*, sword; *sternon*, breast-bone). The inferior or posterior segment of the sternum, corresponding with the "xiphoid cartilage" of human anatomy.

XIPHOSURA (Gr. *xiphos*, a sword; and *oura*, tail). An order of *Crustacea*, comprising the *Limuli* or King-Crabs, characterised by their long sword-like tails.

XYLOPHAGOUS (Gr. *xulon*, wood; and *phago*, I eat). Eating wood, applied to certain *Mollusca*.

ZEUGLODONTIDÆ (Gr. *zeuglê*, a yoke; *odous*, a tooth). An extinct family of Cetaceans, in which the molar teeth are two-fanged, and look as if composed of two parts united by a neck.

ZOŒCIUM (Gr. *zoön*, animal; *oikos*, house). The "cell" or chamber in which the polypide of a Polyzoön is contained.

Zoöid (Gr. *zoön*, animal; and *eidos*, like). The more or less completely independent organisms, produced by gemmation or fission, whether these remain attached to one another or are detached and set free.

Zoophyte (Gr. *zoön*, animal; *phuton*, plant). Loosely applied to many plant-like animals, such as Sponges, Corals, Sea-anemones, Sea-mats, &c.

Zoospores (Gr. *zoön*, animal; and *spora*, seed). The ciliated locomotive germs of some of the lowest forms of plants (*Protophyta*).

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